Mental Physics:
The Architectonics of
Cognitive Systems

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Abstract

Research into cognitive systems, *i.e.*, machines which may in some sense be said to be intelligent, has been undertaken by numerous investigators for many years. One particular aspect of this research is known as Artificial Intelligence research. A second and significantly different research approach takes place under the title of Neural Network research. Yet another activity in this area is known as Knowledge Representation. These three research areas are examples of a "bottoms-up" approach to cognitive systems design. What is specifically missing from this approach is a common architectural theme, *i.e.*, top-down system-level specifications which describe the totality of *all* the computing processes and capabilities which must be present if the machine is to, in any sense, approximate the processes of human reason.

In this essay, we will examine this specific issue. The specific question addressed here is, "What are the fundamental structures and capabilities which must be mechanized in order for a machine to have cognitive capabilities?" This is fundamentally a question of philosophy which was addressed in great detail by Immanuel Kant in the eighteenth century. Kant's work produced a systematic model of the reasoning process in very great detail. In essence, his work established the "physics" of the reasoning process; his theory may be termed the "mental physics" of reason. In this paper, we propose the outline of a reasoning architecture based on the Kantian model and discuss some of the implications of this model.

I. Introduction

If you were to build an intelligent machine, how would you know it? Do any machines currently exist which can "think" in even a rudimentary way? Most researchers would answer the latter question with a definite, "no." The other question would perhaps generate as many different answers as there are research teams. There is a considerable body of research currently in progress directed toward the goal of the eventual design and construction of "intelligent" machines. However, do we clearly understand the objective which we seek?

At present, there is no universal agreement among current researchers on even the definition of the term "artificial intelligence." A dictionary definition of "intelligence" is, "(1): The ability to learn or understand or to deal with new or trying situations: REASON; also: the skilled use of reason. (2): The ability to apply knowledge to manipulate one's environment or to think abstractly as measured by objective criteria." Most people will tend to agree with one or both of these definitions. How is the ability to think abstractly to be measured? The answer most common among researchers in artificial intelligence (AI) is Turing's test [11]. A human examiner sits at a computer terminal and exchanges messages with an unknown correspondent who may be either human or a computer. If, after repeated trials, the examiner cannot tell which correspondent is the human and which is the computer, the computer is declared to be "intelligent."

The shortcomings of the Turing test are obvious. It sets an intimidatingly high and subjective criterion for success which goes beyond the definition given above. One might as well

pose the "Nolan Ryan" test to determine if a person is a baseball player[1]. The Turing test makes no provisions for "lesser intelligences" incapable of reasoning with human proficiency. For example, most people would agree a dog is more intelligent than a bacterium and less intelligent than a human being. Dogs can distinguish their masters from strangers, can be taught tricks, can be taught to herd sheep, and, in the wild, hunt in packs and develop hunting strategies. While some of this can be argued to be mere instinctive behavior, it can be reasonably argued that herding sheep or "acting" in movies is in no way an instinctive behavior and provides evidence of "the ability to learn or deal with new situations."

Lacking a common and reasonable objective metric for measuring "the ability to think abstractly," current research in cognitive systems tends to fall back on subjective measures. Mishkoff [9] has provided some examples of "definitions" of artificial intelligence including the following:

> a) "Artificial intelligence is the study of how to make computers do things at which, at the moment, people are better." (Elaine Rich, *Artificial Intelligence*);
> b) "Intelligence has certain characteristics which include the ability to:
> 1) respond to situations very flexibly;
> 2) make sense out of ambiguous or contradicting messages;
> 3) recognize the relative importance of different elements of a situation;
> 4) find similarities between different situations despite differences which may separate them;
> 5) draw distinctions between different situations despite similarities which may link them"
> (D. Hofstadter, *Gödel, Escher, Bach: An Eternal Golden Braid*, New York:
> (Vintage, 1980)

Another description has been provided by Woods [10] who describes an "intelligent agent" as something which executes a "reasoning loop" defined as "Perceive → Reason → Act → Perceive," *etc*. He leaves unstated his definition of what constitutes "perceive" or "reason" and of the "actions" he says they, "are determined by a set of internal beliefs, goals, and objectives in interaction with what is perceived." His "agent" must acquire a model of its world and keep this model sufficiently consistent with the real world that it can achieve its goals. He holds that knowledge consists of "facts" about what is or has been true and "rules" for predicting changes over time, consequences of actions, and unobserved things which must be deduced from observation. Taken as a whole, his description is, in its essentials, a qualitative description of Kant's philosophy of "critical idealism" [1]-[2].

As representative samples of current "definitions" of the problem, the descriptions just cited illustrate the somewhat nebulous condition of the system-theoretic foundations of work in cognitive systems. Many people are working on the "pieces" of the system but into what systematic structure do these pieces fit? How is the cognitive performance of this structure to be measured? These are the issues with which this essay is concerned.

If we reflect on the question posed at the beginning of this introduction, we soon realize it is much more a question of philosophy than of mathematics, engineering or technology. Further, if we examine the descriptions provided by Hofstadter and by Woods, it seems apparent that there is at least a notion of a *defacto* philosophical system underlying current common thinking about cognitive system research. If this thinking can be systematized into a coherent *structure*, cognitive system research cannot help but benefit.

Woods' "intelligent agent" and Hofstadter's "characteristics of intelligence" share several points in common originating from the philosophy of Kant. In his most important work, *Critique*

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[1]The Nolan Ryan test is: Stand at home plate with a bat; Nolan Ryan throws a 100 miles per hour fastball at you; if you hit it over the center field fence, you're a baseball player.

of Pure Reason [1], Kant set down what may be the most comprehensive and detailed analysis of cognitive reasoning ever attempted[2]. Kant's *Critique* was a revolution in philosophical thought and, since it's initial publication in 1781, has maintained a position of such importance that the majority of current-day philosophers generally hold him to be one of the three most important thinkers in history[3]. His importance for our present purpose lies in his systematizing of the elements of the processes cognitive reasoning.

This essay is an examination of Kant's theory in application to research into artificial cognitive systems. Kant's work is highly technical and his philosophical reasoning contains a number of highly subtle yet vital points. For this reason, it has proven difficult for subsequent philosophers to agree with each other on what Kant's philosophy actually is (although they do agree on its importance). In this article, we shall attempt to set down in a clear fashion those elements of Kant's work which establish a viable *model* of the cognitive processes and we will discuss the applicability and application of Kant's work to this research issue. We will not, in the main, discuss the highly technical philosophical arguments and proofs used by Kant in [1] and [2] as our aim is not to enter into the centuries-old arguments of metaphysics. Rather, we offer the proposition that Kant's work establishes a viable system from which a detailed mathematical model of artificial cognitive systems may be developed. Furthermore, the foundation laid by Kant is meticulous in technical detail and as rigorous in derivation from fundamental principles as any scientific analysis of the subject of reasoning could be.

Since Kant's time, many discoveries and advances have been made in mathematics and the physical sciences. A number of things which were "facts" believed in Kant's day to be beyond dispute have since fallen into disrepute or have proven to be false. Kant lived at a time before the development of axiomatic set theory, before the discovery of non-Euclidean geometries, before the antinomies of mathematics in this century leading to the splintering of mathematical philosophy into the "schools" of Platonism[4], Formalism, and Constructivism [12], and even before the full development of the techniques of classical (to say nothing of relativistic and quantum) physics. Any person with a healthy amount of scepticism is entitled to ask, "What can a man who has been dead for nearly two centuries tell us about a modern-day technical problem?" If the issue at hand were technical design aspects of a new computer or a high-efficiency gasoline engine, Kant would have little to contribute to the discussion. However, the problem at hand is *not* a narrow question of technology; rather, it is precisely the question of "what does it mean 'to think'?" and for *that* question, Kant's work is foundational. It stands as evidence to his genius that none of the above-mentioned developments abolishes or significantly alters any of the results of the *Critique* and, indeed, he may be said to have anticipated something generally (if not specifically) like these changes[5] would occur.

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[2]The works of Hegel and of Whitehead are also comprehensive and highly technical; however, Hegel's system has fallen out of favor over the years [3, pp. 402-431] and Whitehead's philosophy of Pragmatism has not achieved particularly widespread support; by contrast. *Critique of Pure Reason* remains a vital foundation for most current-day philosophies of science.

[3]The other two, by most popular standards, are Plato and Aristotle.

[4]Platonism, as currently defined in discussions of the foundations of mathematics, was the mathematical philosophy of Kant's day.

[5]As a mathematician, Kant would probably have found the discoveries of non-Euclidean geometry or Russell's Paradox to be deeply disturbing and these, as well as the "incompleteness" theorems of Gödel and Cohen, undermine several of his explanatory "demonstrations" in the *Critique*; however, the fallacies revealed by these developments are the product of axiomatic mathematics and in his "Transcendental Doctrine of Method" Kant demonstrated the dialectic fallacy of *basing* a theory of reason on axiomatic mathematics [1, pp. 522-539]; the "crisis in the foundations" which occurred in mathematics in this century [12] would probably have been regarded by Kant as another example of misunderstood application of transcendental dialectics and, had he lived to see the general theory of relativity, it is plausible to believe he

Still, it is, as Kant might have said, the *duty* of this essay to demonstrate the applicability of this theory to the present issue as well as to point out any places where Kantian philosophy may be inadequate for the task at hand. We shall presently do this. At this point, we will simply invite the reader to hypothetically accept, for now, a thesis that Kant's system provides the model we require to systematize the discipline of research on artificial cognitive reasoning systems. If, afterwards, he choses to reject this thesis, that is his perogative. Let us now proceed with the subject at hand.

II. Basic Elements of Kant's System

The level of technical detail and the pedantic style of its presentation, as well as the slow erosion of the crisp meaning of certain words over the intervening centuries, makes Kant's work difficult to follow and, in some places, obscures his original meanings. Philosophers past and present are in near agreement on the difficulty of Kant's writings. For this reason, we feel compelled to attempt a translation of Kant into more modern language and to summarize in some detail the main points of his system. It would be inappropriate to simply reference the *Critique* and the *Prolegomena* [2] in the expectation of having the reader "do his homework" in this subject. Indeed, the *Critique* is a serious document and the study of it is not unlike a journey on foot of many miles through a land of ankle-deep mud. The author's own journey through Kant would not have been possible without the assistance of a number of insightful commentaries and criticisms from other works, notably, [3], [7]-[8]. In what follows, we merely *summarize* Kant; his proofs are developed throughout [1] and there let them stay[6]. Kant is our starting point and we have far to go to reach our present objective.

Our first step must be to set down the most fundamental of Kant's principles [7, pg 265]:

1. All knowledge is the product of two factors, the knowing subject and the external world;

2. The external world "lends to our knowledge its material" through the mechanism of experience;

3. The knowing subject furnishes the *form* this knowledge will take.

Kant does not say the knowing subject knows the external world as it "really" is; the external world, when perceived by the knowing subject, is "filtered" through the senses before being presented to the mind. Consequently, the knowing subject can never truly *know* if the world is "really" the way the subject "thinks" it is. The knowing subject must be content with a model of this world; this model is produced and exists solely in the "mind" of the knowing subject. The way in which the "mind" is constructed and operates is responsible for what form this model will take. Kant calls things in the external world the *noumena*[7] while things as perceived, conceived,

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would have regarded this development simply as an empirical demotion of Euclid's fifth axiom from the status of knowledge *a priori*: indeed, mathematical axioms are nowhere incorporated into his theory and, in fact, are explicitly banished as fundamental principles in the theory of reason; in his own words, "I shall be satisfied with showing that none of these forms," (mathematical definitions, axioms, and proofs), "can be employed or imitated in philosophy in the sense in which they are understood by mathematicians" [1, pg. 531].

[6]If the reader once becomes satisfied that Kant provides the foundation we need for cognitive system research, he may wish to undertake his own study of the original work; be warned, however, that the *Critique* may not be skimmed and understood: Kant discusses a wide universe of inter-related issues and uses many adjectives with very precise and vital technical meaning; his arguments and proofs and even the meaning of some of his words are, in a sense, recursive in that illumination of his early points often does not come until discussion of topics one hundred or more pages later; unfortunately, this means the *Critique* must be read in virtually its entirety and from beginning to end if one is to understand any particular part of it; failure to do so will most likely result in nothing but confusion and misunderstanding.

[7]*Noumena* is an untranslatable word which is usually rendered approximately as "the things in themselves."

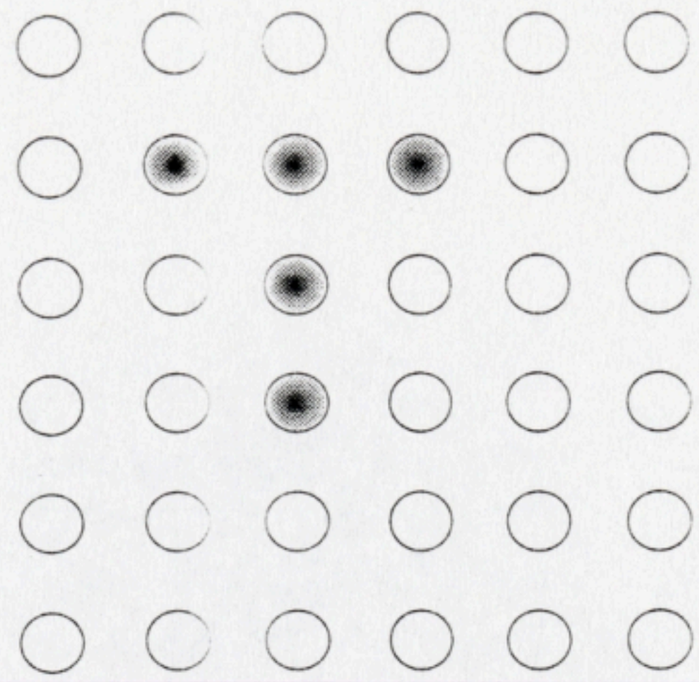

Figure 1: Input Sensor Array

and represented in the mind make up the *phenomena*[8]. Any knowledge which arises completely independently of any possible experience is termed "pure knowlege *a priori*" while that which can can have *only* an empirical origin is termed "knowledge *a posteriori*." Knowledge which independent of any specific experience but which arises from empirical considerations, such as the proposition, "Every change has a cause," is termed "impure knowledge *a priori*."

Let us make these ideas clearer by means of an example. Suppose we had a hypothetical machine capable of cognitive reasoning (in a sense to be made clearer later). Further imagine this machine can only receive inputs of any kind by means of an array of binary input sensors. Figure 1 illustrates this hypothetical input grid. Let us further assume that we, as the designers of this machine, have supplied it with no information whatsoever of the nature of the world we know and live in, *i.e.*, we have supplied it with no *a priori* knowledge of the world as we know it. All that this machine can ever learn of its universe must then be based on the sensuous data it receives via this input grid.

Since we have supplied it with no *a priori* knowledge of color and since its input grid is binary valued, this machine will never be capable of conceptualizing "color." Let us make a further refinement. Suppose the sensor grid is actually an array of pressure sensors on the floor of a room which respond with an "on" signal whenever some object (a person, a table, or the family dog) steps on a sensor with a weight greater than five newtons. Since our hypothetical machine is assumed to be capable of reasoning and to be inclined to do so, it will construct for itself a model of the world of its sensuous perception. As we have supplied it with no knowledge of the world as we know it, the machine's model will clearly be vastly different from our own. To the machine, our world is composed of *noumena* and, with a small amount of imagination, we can picture for ourselves the kind of possible phenomena the machine will construct for itself to represent this world (assuming the machine reasons in a manner similar to our own).

Let us now turn to the basic knowledge elements of Kant's system. We have already alluded to the distinction between knowledge based on empirical experience and knowledge which goes beyond empirical experience. The existence of knowledge *a priori* is well established in philosophy [1]-[3] and it is clear we could supply any machine of our own design with whatever form of *a priori* knowledge we wished. However, inasmuch as the primary goal of most research in cognitive reasoning systems is aimed at achieving human-like responses, the *Critique* tells us there is a core set of pure knowledge *a priori* which *must* be present in the system. The

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[8]When one tries to extend phenomenal conceptions to apply to the *noumena*, one is committing an error which Kant terms a *transcendental illusion*.

absence of any element of this set renders impossible the achievement of human-like reasoning by the system.

All knowledge elements are classified either as *intuition* or *conceptions*. These terms are defined by Kant within his taxonomy of knowledge representation. Kant's taxonomy is presented in Table I below. Intuitions and conceptions may be either *pure* or *empirical*. Knowledge is empirical if sensation is contained within it. Knowledge is pure when no sensation is mixed in with the representation.

Table I
Kant's Taxonomy of Knowledge Representation

Perception: Representation with consciousness
Sensation: A perception relating solely to the subject as a modification of its state
Cognition: An objective perception either in the form of an intuition or a conception
Intuition: A singular and individual cognition with immediate relation to the object
Conception: A cognition with a mediate relation to the object by means of a characteristic mark which may be common to several things
Notion: A pure conception having its origin in the faculty of understanding and which is not the conception of a pure sensuous image
Idea: A conception formed from notions which transcends the possibility of experience; also called a concept of reason

Mental faculties can be classified into two main sources of knowledge. The first of these is the faculty of receiving representations from the external world. This faculty is termed the *sensibility*. The second is the faculty for cognizing by means of these representations. In Kant's system, this second faculty is further subdivided into a faculty of *rules*, a faculty of *principles*. The faculty of rules is called the *understanding* and the faculty of principles is called the *reason*.

Sensibility is the province of intuition. It separates the sensations from the objective representation of the phenomenon and supplies this representation to the faculty of the understanding as illustrated in figure 2. Kant's theory distinguishes three faculties within the sensibility. The first is the empirical intuition which cognizes those aspects of the phenomenon directly given by the sensation. Kant calls this part of the representation the *matter* and the knowledge represented therein could include such things as color, taste, smell, and so forth.

The *form* of the phenomenon is that which does not contain any object of the senses and is cognized by the pure intuition. The pure intuition is the source of the knowledge *a priori* provided to the sensibility. Within Kant's transcendental philosophy, the nature of pure intuition is called the transcendental esthetic. The results derived from the transcendental esthetic, which we will discuss in more detail later, show there are two and only two pure intuitions: Space and

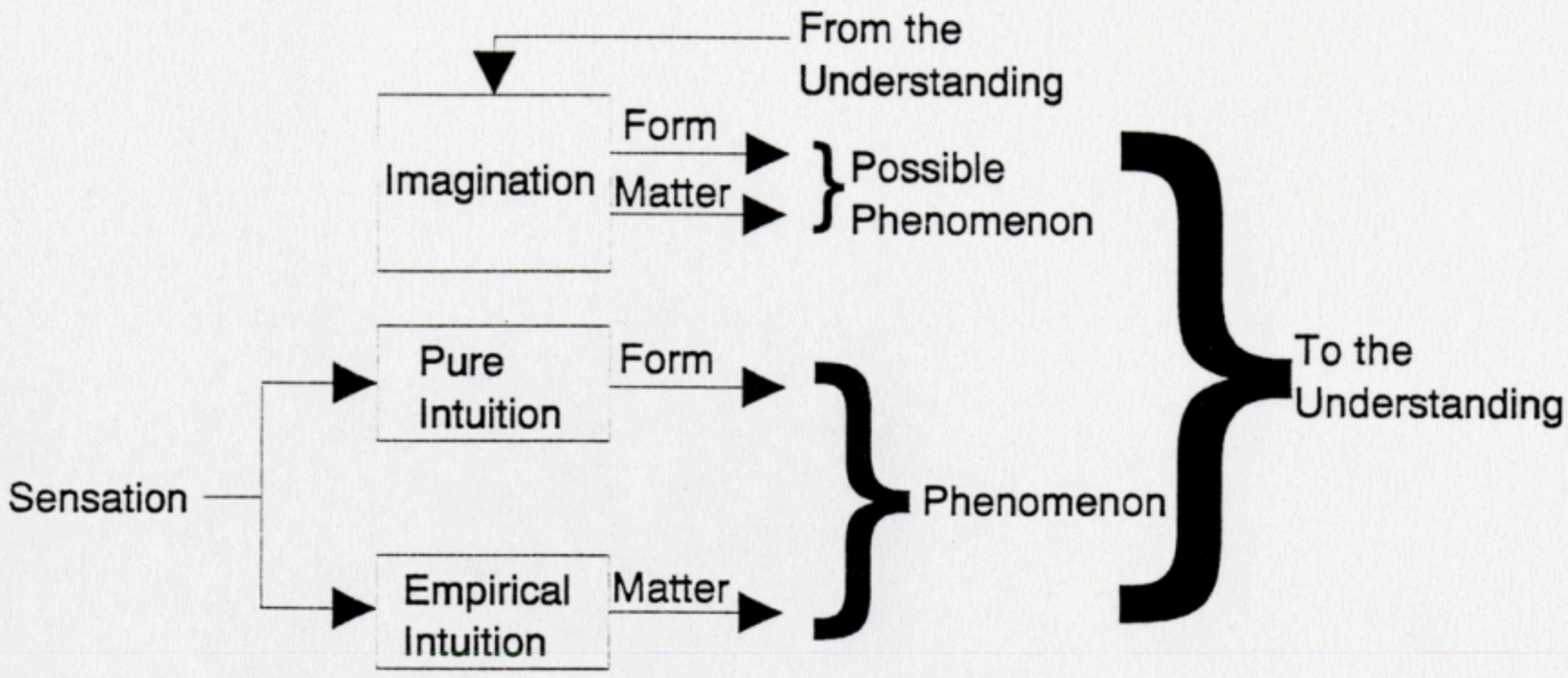

Figure 2: The Faculty of Sensibility

Time. The form of the phenomenon therefore represents it in terms of spacial and temporal relations.

The distinction between form and matter can be viewed as a distinction between properties of the sensation itself (matter) and properties not properly part of the object of sensation, *i.e.*, its location in space and sequence in time. That there is a distinction between the matter ("a house") and the form ("over there") is clear. The shape, taste, smell, and color of an object of sensation may be properly said to "belong" to that object. Where I perceive it to be in space and when I perceive it to produce the sensation by it comes into my consciousness are not properties of the object itself.

The intuition responds to sensation and produces a representation in matter and form. However, the process of thought often requires the ability to perceive an object in its absence. This is what we mean when we say things like, "Can you picture this?" or "What did that man look like?" The sensibility contains a faculty for producing representations of objects of the senses when those sensations are absent. This is the faculty of imagination. The imagination is commanded by the faculty of the understanding and responds by producing the representation in matter and form of the requested object of *possible* sensation. For example, I have never seen a duck with blue feathers wearing a beret but I can *imagine* such a thing[9] and picture it clearly "in my mind's eye." I am equally well able to recall this morning's breakfast and, if I concentrate, can do so even to the extent of being able to taste the eggs and hear the bacon sizzling.

The task of the imagination is to produce the intuitive representations of sensible conceptions[10] of the understanding. The matter and form of these representations are the same as that of the intuition. In the case where the understanding is calling for a representation of a previous perception, the task of the imagination is simply that of recalling that perception from memory. However, in the case of a possible but not previously given perception, such as the blue duck, the imagination must be able to synthesize the various elements of matter and form being requested. Its role, therefore, is more than simple memory. The example of a blue duck is, in principle, a simple one: Take a previous image of a duck, delete its color representation, and

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[9]The fact that there are no blue ducks does not preclude the *possibility* of seeing one; an enterprising teenager with a can of blue spray paint and a sense of humor *might* produce a blue duck and, if I am in the vicinity, I *might* see it.

[10]A sensible conception is a conception which corresponds to a possible sensation that could be represented by the intuition.

replace the color representation with "blue." However, the requests of the understanding can be more complex than this as, for example, when the understanding requests a representation of the duck's beak *without* the rest of the duck. As this example illustrates, *disjunctive* as well as *conjunctive* modifications to previous matter must be possible.

The imagination must be capable of representing changes in form as well as matter. Various rotations, translations, and reflections in spatial orientation ("duck facing the other direction") as well as different time sequences ("duck waddling backwards") must also be among the capabilities of the imagination. Since the imagination does it work at the direction of the understanding, it is clear there must be an intimate connection between the faculty of the imagination and the representation of conceptions within the faculty of the understanding.

The sensuous faculty (the sensibility) can not think. Intuitions can never be other than sensuous and immediate. The sensibility supplies intuition but contains no *conceptions*. Conceptions are the province of the understanding and the role of *thinking* falls to the faculty of the understanding[11]. Before describing the understanding, however, we must pause to define what is meant by the verb "to think."

From the time of Aristotle, we have inherited an operational definition of thinking [4]. For Aristotle, to think is "to make judgments." In turn, to judge is "to affirm (or deny) the predicate of a subject in a logical proposition." The equating of "to think" with "to judge" is still current in modern thought although Kant broadens the definition of judging. To Kant, judgment is "the union of representations in one's consciousness." The fundamental particular act of any single judgment is still the same for Kant as for Aristotle, *i.e.*, affirming or denying the predicate to the subject in a logical proposition. However, Kant enlarges the picture. The sum of all such individual judgments must form a consistent whole. For example, I may assert, "I am younger than my sister." I may also assert, "I am older than my sister." However, I can not hold, unqualified, both of these judgments in my consciousness together because these propositions are contradictory. I can, however, hold the judgments, "I am younger than my sister, Sherri," and, "I am older than my sister, Melody" simultaneously in my consciousness without contradiction.

The tasks of the understanding are: 1) to form elementary judgments from logical propositions, and; 2) to continually act to create and maintain a unified and consistent whole among *all* elementary judgments. The key to (2) is the formation of *hypothetical* judgments (syllogisms), the derivation of *necessary* judgments which follow from the syllogisms, and the constant enforcement of *unity* of the judgments as a whole (resolution of contradictions). These acts are carried out by the understanding under the direction of the reason whose role is to direct the understanding as to what it, the understanding, is to think *about*.

To appreciate the task of the understanding, it is necessary to be aware that there are two distinct types of judgments, namely, judgments of *perception* and judgments of *experience*. A judgment of perception merely compares perceptions and connects them in consciousness in a particular state. For example, "the milk is sour" is a judgment of perception which unites the conception "milk" with the conception "sour." Let's follow this example a bit more closely. Let's say I have previously been given a perception from which I have developed, in the understanding, a conception we will label as "milk." Let's say my understanding also contains, from some other previous perception, a conception called "sour." The conception "sour" is defined by a certain sensation of taste and odor in combination, *i.e.*, a certain relation of *matter*[12].

Let us now say my faculty of the understanding is presented with an intuition we will call "sourmilk." Comparing one part of the matter of "sourmilk" to previous conceptions, I find

"sourmilk is milk,"

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[11]The understanding can not intuit; intuition is the exclusive province of the sensibility.

[12]The definition of "sour" would, itself, be a judgment of perception.

i.e., this object is identified through properties of its matter as a particular occurrence of a class of objects previously defined as "milk." This is a judgment of perception. Going further, I find the matters for taste and odor consistent with my prior conception of "sour." Hence,

"sourmilk is sour."

Combining these two with the form of the intuition ("now"), I arrive at "the milk is sour." When I am asked, "where is the milk?" tomorrow, I will remember this judgment (through exercise of the faculty of my imagination), judge from the current form of my intuition that "that was then and this is now," and I will say, "The milk *was* sour. I threw it out[13]."

A judgment of perception is of subjective validity only. In the above example, *I* won't drink the milk but perhaps my sister will. Just because I think the milk is sour does not guarantee my sister will think so. A judgement of perception has no *universality* (the milk isn't sour for everyone) nor any *necessity* (milk does not *always have to be* sour). The case with judgments of experience is quite different.

A judgment of experience is one which has universal validity, *i.e.*, validity which does not depend on the subject (me) but will and must hold true for others. In other words, it is a judgment with *objective* validity[14]. To achieve such validity, the judgment must be founded on conceptions with universal validity; in other words, such judgments have their origin in the pure knowledge *a priori* which is possessed by *all* reasoning agents.

Earlier, we divided the faculty of the intuition into "pure intuition" and "empirical intuition." Empirical intuition responded directly to sensation but pure intuition went beyond sensation and supplied form to the perception by providing representation in Space and Time. Space and Time are pure and *a priori* intuitions.

In a like manner, the faculty of understanding is in possession of some pure *a priori* concepts. These conceptions are "built in" to the reasoning agent and form the fundamental structure of how this agent "thinks." Kant identified these concepts and found there are exactly twelve of them and they are the same for all entities capable of human reasoning. These twelve fundamental conceptions, which Kant named *the categories*, make up the universal *functions of understanding*.

A judgment of experience is a judgment which involves one of the conceptions of understanding (*i.e.*, one of the categories). Let us illustrate this with a specific example. One of the categories is the concept of Causality and Dependence. This category holds that *every change has a cause*. Let us assume I have previously "had an experience" where something which was formerly cold to the touch when I first encountered it had become warm to the touch the next time I encountered it. I don't know *why* this happened (we assume), but I nonetheless form the judgment,

"something (call it 'heat') *causes* warmth."

Now let us suppose I have a perception of a rock in the sunlight. I make the following judgments:

1. The sunshine is on the rock	(judgment of perception)
2. The rock is warm	(judgment of perception)
3. Sunshine warms the rock?	(hypothetical judgment of experience)
4. Sunshine is heat	(necessary judgment of experience).

Judgments 1 and 2 are simply judgments of perception. Since I have presumably seen both rocks and sunshine before and have formed the conception of "warmth," these judgments do not supply me with any basically new knowledge which goes beyond *this* rock at *this* time.

Judgment 3 is where the new experience begins. The category of causality requires me to postulate that something caused the stone to be warm. Let's say I had noticed the stone was cool

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[13]Can you spot the judgment of perception in this second example?

[14]Its validity is grounded in the object being perceived and not in the observer doing the perceiving.

earlier today but it warm now. What is different? Well, the stone has been exposed to sunshine all morning. Perhaps sunshine caused the stone to get warm. This is a *hypothetical judgment* of experience involving the *a priori* conception of causality.

Now, I do not *know* for certain that sunshine caused the rock to be warm. This is a hypothesis. How do I know my sister didn't bake the stone in the oven and leave it outside for me to find? This is where judgment 4 comes into the picture. *If* heat *causes* warmth *and* if the sunshine warmed the stone, *then* sunshine *must* be a form of heat.

The above is known as a syllogism. The proposition "heat causes warmth" antecedes the judgment "sunshine warms the stone." The former is called the major premise while the latter is called the minor premise. The *conclusion* of the syllogism is "sunshine is heat." Notice this conclusion is a *necessary* consequence of the hypothetical judgment (3). If judgment 3 is true, then judgment 4 must necessarily *also* be true.

Notice we do not conclude we know everything about "heat." We cannot rule out the possibility that there may be other forms of heat. "Heat" is an abstract conception we formed through a judgment of experience earlier. "Sunshine" may simply be a particular element of a *set* of things belonging to "heat" in much the same way Tom, Dick, and Harry are *particular* elements of a set of things called "men."

We also do not know for sure judgment 3 is true. An encounter with "cold sunshine" where leaving something out in the sunshine seemed to result in the object getting colder would set up a contradiction to the *necessary* judgment "sunshine is heat." Such a contradiction would give the understanding "something to think about" because *contradictions in the cognitions of the understanding may not be tolerated.*

Consider the significant distinction between a judgment of perception and a judgment of experience. In the judgments of perception, there is oftentimes a very strong flavor that the predicate of the proposition is actually present in the subject practically by definition. For example, suppose the understanding has been presented with several intuitions we will call rock1, rock2, rock3, and so on. From these intuitions, let's say the understanding has formed a conception called "rock." In order to form such a concept, "rock" must have defining properties presented in the matter of the intuition. One of these properties might be the sensation that the objects which make up the set "rock" have a sensation of touch which can be quantified into the concept "hard[15]." If the understanding is now presented with another intuition and forms the judgment of perception, "the rock is hard," this judgment adds no new knowledge because the property of being "hard" is part of the definition of the concept "rock." The subject carries the predicate within it.

On the other hand, the judgment of experience "sunshine is heat" goes *beyond* what is immediately given in the intuition and *beyond* any defining property of the concept "heat." Let's look again at the syllogism

Heat causes warmth; the sunshine warms the rock;
(therefore) sunshine is heat.

The hypothetical judgment of experience "the sunshine warms the rock" goes *beyond* what is presented in the intuition and beyond any previous conception of the understanding. It is something totally new in the experience of the understanding. The new element arises from the pure *a priori* concept of causality. The cognition "sunshine warms the rock" can not arise from the intuition. It is placed there by the understanding.

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[15]We will discuss this in more detail later; Kant's theory calls for the association of a number. called "intensive quantity," with every sensation presented by the matter of intuition; for present purposes, we will assume any intensive quantity of touch greater than some certain amount will be tagged with the definition of being "hard."