To borrow an illustration from chemistry, butyric acid is a different substance from propyl formate. Yet both are made up of the same chemical substances, carbon (C), hydrogen (H), and oxygen (O), and that, too, in like proportions – namely, C4H8O2. If now we equate butyric acid to propyl formate, then, in the first place, propyl formate would be, in this relation, merely a form of existence of C4H8O2; and in the second place, we should be stating that butyric acid also consists of C4H8O2. Therefore, by thus equating the two substances, expression would be given to their chemical composition, while their different physical forms would be neglected.

If we say that, as values, commodities are mere congelations of human labour, we reduce them by our analysis, it is true, to the abstraction, value; but we ascribe to this value no form apart from their bodily form. It is otherwise in the value relation of one commodity to another. Here, the one stands forth in its character of value by reason of its relation to the other.

—Karl Marx, Capital Volume One, Section 3

1.

In the above passage, Marx locates the limitations of the rationalist economic mindset in the material specificity of chemical substances. It is a pointed example for anyone familiar with the odor of these two compounds: propyl formate is a commonly used "artificial flavor" ester with an ethereal, fruity note at that time common in perfume compositions; butyric acid on the other hand has the characteristic odor of rancid milk and butter. The limitations of (literal) atomization are found here in the difference between the empirical formula for the two substances (C4H8O2)—which is identical for both and unable to account for their radical phenomenological and formal difference—versus the structural formula, which prioritizes the relations between the component atoms in the differing molecular structures.

From this basis in concrete, indivisible material structure—the root 'chemical signature' of a material—Marx goes on to explicate the notion of abstraction as the central driving force and characteristic of capitalist society. This abstraction arises first from the *relations* of commodities to one another, mediated by the exchange process. The true structure of capitalist society, like the true structure of matter resides in the relationality of its components. In this relation of commodity to commodity an abstract form of value arises as a free-floating entity that is not connected to any item in particular. It is this "value form" that allows for the social phenomenon of currency—a material that embodies this abstract value in an arbitrary physical form and allows any thing to be exchanged for any other thing of equal value in a "fraternization of opposites."

Crucially, the potential exchangeabilty of all things through the medium of abstract value, promotes the "congelation" of human labor into "abstract labor" which becomes a commodity in its own right (leading to the classic idea of alienation). The capacity to work, irrespective of what particular tasks it is applied to, becomes an abstract, yet thoroughly "real" entity—affecting every step of the production processes.

> It is the expression of equivalence between different sorts of commodities that alone brings into relief the specific character of value-creating labour, and this it does by actually reducing the different varieties of labour embodied in the different kinds of commodities to their common quality of human labour in the abstract
>
> Human labour power in motion, or human labour, creates value, but is not itself value. It becomes value only in its congealed state, when embodied in the form of some object. In order to express the value of the linen as a congelation of human labour, that value must be expressed as having objective existence, as being a something materially different from the linen itself, and yet a something common to the linen and all other commodities. The problem is already solved.

The question of where this abstract value can exist physically in a material form becomes paramount. It is from this point that Marx goes on to formulate the notion of *real abstraction* as the fundamental operating mechanism of capitalist society—the tendency to make abstract categories function as things in themselves. However, despite the fact that Marx states "The value of commodities is the very opposite of the coarse materiality of their substance, not an atom of matter enters into its composition." The defining characteristic of the concept of real abstraction lies in its focus on the concrete in the form of the material, social practice that underlies and precedes the abstract, subjective value calculation of the exchange act.

In the classic example of currency, it can easily be said that the abstract value of an arbitrary material—such as gold or coinage—arises as a result of the individually and collectively held beliefs of the society that accepts its value. However, Marx inverts this premise to state that these thought processes are in fact a reflection—a mental reduplication—of the pre-existing social structure. The social relations—the synthetic mode of society—are already inscribed in the thought before it occurs, and furthermore can exist independently of it. As summarized by Alfred Sohn-Rethel, perhaps the pre-eminent thinker on the concept of real abstraction in the 20th century, it is "an abstraction other than that of thought" (Sohn-Rethel, 1978: 302):

> The essence of the commodity abstraction, however, is that it is not thought induced; it does not originate in men's minds but in their actions. And yet this does not give "abstraction" a merely metaphysical meaning. It is abstraction in its precise, literal sense […] complete absence of quality, a differentiation purely by quantity and by applicability to every kind of commodity and service which can occur on the market' (Sohn-Rethel, 1978: 20).

The abstraction of the exchange process is located in the social behavior of the act of exchange—the cognition of the exchange process is simply a re-enactment of the pre-existing social array. "It is the action of exchange, and the action alone, that is abstract." (Sohn-Rethel, 1978: 20)

A paradox appears as to how an operative social abstraction can arise in the absence of thought. For Sohn-Rethel, the process can be traced to a kind of gradual symbiosis or convergence between cultural mindsets and the practical, material operations that underpin them. The development of the modern commodity form, for example can be speculatively traced to Egyptian standardized measurements. In particular, a system of triangular rope measurement became widely adopted in Egypt as an administrative method to measure and re-establish land boundaries in areas that are annually flooded by the waters of the Nile[1]. Over the course of many centuries this system developed into its more abstract form in Greek geometry and trigonometry. Along with this, a process of expanding trade relying on previously established standardized measurements promoted the development of mathematics and abstract calculations, which could then be re-incorporated into the social practice of exchange—a process that, crucially, occurred in tandem with a geographic expansion of the currency system in the form of coinage. For Sohn-Rethel, this early development

[1] This system is of course, already dependent upon the abstraction of land ownership or use rights that can be linked in part to the development of agriculture. Egyptian society is also notable in its system of administration to a stored surplus of agricultural production.

of the commodity form, along with coinage, forms the basis for abstract and logical thought as it has developed subsequently in history.

Here, the two-fold movement of real abstraction becomes apparent, in that not only does the social formation precede abstract thought, but that abstract thought in turn becomes an operative entity within the social formation.

Following this classical narrative of development—which culminates in a marked intensification of systems of abstraction under the Industrial Revolution and Taylorism, the question of the specific nature—the "materiality"—of real abstraction within contemporary society comes to the fore as a ground for speculation. Several "Post-Fordist" theorists have pointed to a change in the nature of labor and abstraction in the period roughly corresponding to the rise of cultural post-modernism. At the same time that production processes began to become increasingly automated, labor began to take on a more "cognitive" or "performative" quality. Rather than segmented, Taylorized tasks, an emphasis is placed on procedural understanding, "know-how," and interpersonal or cooperative, quasi-managerial or scientific skills. Paolo Virno sees this development in correspondence with a shift from labor in the abstract to the "general intellect"[2] as the primary productive force. The abstract capacity for labor is supplanted by the abstract capacity to think—to labor cognitively, flexibly, and cooperatively at a moment when "thought becomes the primary source for the production of wealth" (Virno, 2002: 64) and "mental abstractions are immediately, in themselves, real abstractions."

For Virno, this colonization of intellectual capacity by production processes is an acceleration and intensification of the processes of real abstraction, at the same time that it points to a qualitative shift in the underlying basis of society:

> Because it organizes the productive process and the "lifeworld", the general intellect is indeed an abstraction, but it is a real abstraction, endowed with a material and operative character. Nevertheless, since it consists of knowledges, informations, and epistemological paradigms, the general intellect distinguishes itself in the most peremptory manner from the "real abstractions" which were typical of modernity: those, that is, which give rise to the principle of equivalence. While money, i.e. the "universal equivalent" embodies in its independent existence the commensurability of products, labour, subjects, the general intellect establishes instead the analytical premises for every kind of praxis. The models of social knowledge do not equate the various laboring activities, but present themselves as "immediate productive force". They are not a unit of measurement

[2] While Marx emphasizes the "fixed" idea of the general intellect as it is embedded within machines and explicit production processes, Virno expands the concept to include the intellectual capacities required for production more generally.

> but constitute the immeasurable presupposition for heterogeneous operative possibilities. (Virno, 2002: 149-150)

Not coincidentally, this image of fragmented procedures and incommensurate operations bears a resemblance to the condition of post-modern scientific practice as described by Jean-Francois Lyotard in The Postmodern Condition: A Report on Knowledge. Here, in the absence of a "meta-narrative" that can serve as the universal "guarantor" of the legitimacy of scientific knowledge, the self-critical operation of science has developed into a fractured archipelago of localized and incommensurate "language-games"—each with its own set of axioms, procedures, grammar, and protocol. Statements within these language games are valued for their *difference,* in their ability to contradict previous statements and commonly held assumptions within the localized history of a particular game. Progress occurs on a model of *parology* or the production of paradox.

> Post-modern science – by concerning itself with such things as undecidables, the limits of precise control, conflicts characterized by incomplete information, "fracta," catastrophes, and pragmatic paradoxes – is theorizing its own evolution as discontinuous, catastrophic, non-rectifiable, and paradoxical… It is producing not the known but the unknown. (Lyotard, 1984: 60)

I would argue that it is a model of parology on which the 'financial sector' now operates. For both Virno and Lyotard, the possibility of equivalence has been superseded—be it in the form of the legitimating narrative or the exchange principle. And for both of them, *difference* becomes the new operative value. I would propose that the condition for this shift is not in the disappearance or obsolescence of the principle of equivalency in the relations of exchange, but rather its *concretization*.

2.

The importance of the historical concept of real abstraction becomes apparent when we turn our focus toward the conditions of the present-day and what has variously been called the ascendance of network technology, the internet, digital media, et al. This shift in particular (and Post-Fordism more generally) has often been referred to as a large-scale force of "dematerialization" in both culture and finance. The question arises as to what is the specific materiality of this supposedly "immaterial" condition.

From the Egyptian system of rope measurement and the Greek system of coinage, a speculative line can be traced to the mechanical looms of the Industrial Revolution and eventually the first automated looms which—like the first computers that were partially derived from these advances—ran on a system of punch-cards that are often considered as the first software or program.

Related to these developments, Charles Babbage's "difference engine" and the development of the logic gate demonstrated a capacity for a logical operation to be embodied in a physical structure or mechanism. Logic gates use the flow capacity of electrons through different types of connections to perform operations by modulating their output (a principle that can also be applied to water flowing through conduits and other flowing materials). It was discovered that the wiring of certain types of electrical circuits can correspond to logical-grammatical statements or operations (using the Boolean logic system). A circuit wired in parallel corresponds to an OR statement[3]; a circuit wired in series corresponds to an AND statement[4]. By assembling these circuits together into a larger circuit, a complete logical statement can be constructed. Running a current through this circuit-statement will yield a specific output (either "on" or "off"). The statement can then become a question, and the electrical output of the circuit-statement either negates or verifies its truth value.

[3] If two switches are present in the circuit, the circuit will yield an electrical output signal if either one OR the other switch is on.

[4] A series circuit will only produce an output if both the first switch AND the second switch are on.

The principle of equivalence, which underlies and makes possible logical abstractions is physically embedded in this functional, material array. Beyond Sohn-Rethel's location of the possibility for logic and abstract reasoning in the relational equivalence of the commodity form, there is an elegant formal and material equivalency between the structure of logic and that of matter/energy in the form of electrons flowing through the circuit. The fundamental logical operator is itself *equivalence* and the electrons act out this operation based upon whether they can return to their point of origin: if they can physically traverse both sides of the equation-circuit, then both halves of the equation are whole—there is a correspondence[5]. In this case, a physical and conceptual movement can occur between the two entities to be compared and there will be an output charge verifying the equivalency statement. In their circulation capacity, the electrons behave as abstract value.

The logical operation—like Marx's equation between molecular and social structure—arises from a *material relation.* Arrangements of material can directly correspond to operations of thought (which are themselves, of course, always material). In this moment we can see the beginning of a shift in the nature of real abstraction. What began as a social reality that precedes thought (and a thought-based category that becomes operational in the social reality) yields to an abstract thought that is functionally embodied in a technological apparatus and concretized. The operational capacity of an abstract category is made physical, and this encapsulated, technological thought-form becomes the subsequent basis for "external" social reality. The dynamic appears as a reduplication of a reduplication of a reduplication where each stage can be viewed as simultaneously an abstraction and a concretization of the previous stage.

One of the key aspects of the material operationality of digital systems is a functional architecture of recursion. From the basic logic gate or transistor, which operates as a result of a circular, reoccurring flow of electrons; to the level of software, where tasks can be flexibly automated through recursive grammatical commands[6]; through to the integration of multiple programs and subroutines within the operation of a single processor; and finally, the integration of multiple systems into an active network, each level is marked by a dynamic of recursion, where outputs are "fed back" into and modify inputs. The development of the field

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[5] Interestingly, this relation is echoed in the symbols for equivalence and non-equivalence in mathematics: "$\equiv$"and "$\not\equiv$," respectively, where the function of equivalency can be envisioned as a passage, conduit, or an ability to travel between two sides. In the non-equivalency sign, the passage appears blocked and travel or flow cannot occur.

[6] It could be said that the most common command in all programming languages is "repeat."

of cybernetics and network technology itself relied heavily on an abstraction of the market as a "self-correcting system" —a system that changes its state in response to incoming information and registers its own output. However, as has often been observed in both the phenomenon of feedback and the history of the market, a recursive system is equally as likely to produce crisis[7] as a normalized signal[8].

I would argue that what appears as the fragmented, incommensurate, nature of production, exchange, and scientific inquiry (as well as media and culture) is the result of this shift toward recursion[9] as the operative form of abstraction in society. When the outputs of a system are fed back into its inputs, the progression of the system is heavily affected by the pre-existing dynamic state and the material specificity of that system—whether it is a system of scientific inquiry or procedural protocols or the system of financial exchange itself. An increased emphasis is placed on the ability of a particular dynamic, procedure, or mechanism within the system to perpetuate itself—all activity becomes focused on the bottleneck of recursion.[10] Although a system processes information from its "external" environment[11] it can only register this information through the functional architecture of its own pre-existing frame, which requires that incoming information can be compatible with the system's logical-material and recursive requirements. The particularity of this frame is repetitively stamped into and thoroughly imbricated in the reduplication of the external environment within the system. Recursive dynamics tend towards self-referentiality, acceleration and a magnification of their particular input/output dynamics (often a magnification of accident) which tends towards the evolution of both autonomization and incommensurability.

Both Lyotard and Frederic Jameson have pointed out that while the ground for developing the digital technologies of memory banks and remote data transfers was in the academic and scientific world, these technologies were quickly adapted and their growth spurred by their ability to track and store vast arrays of financial data. This allowed for a paradigmatic expansion and acceleration of the currency system in the form of financial capital—a mutation in the nature of currency itself. The logical abstraction and the tracking capacity inherent to currency is transferred to a physical logic system that can track values internally with

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[7] Consider, for example the "2010 Flash Crash" also known as "The Crash of 2:45"

[8] Many of the most common errors in computer programming result in an "infinite recursion" or recursion exception that causes a program to crash or freeze.

[9] Specifically, a concretized form of (technologically or administratively) mediated recursion. Of course, generally speaking, recursion is a crucial facet of culture and its perpetuation beyond its contemporary mutation.

[10] Here we can see the relevance of Louis Althusser's analysis of the "ideological state apparatus" as a mechanism for ensuring recursion in the "reproduction of the relations of production"

[11] In cybernetics theory an external entity affecting a system is technically a part of the system.

unprecedented speed and complexity. More so even than the classical embodiment of the real abstraction, this concretized abstraction can operate entirely without the subject's awareness.

> The results of these lightning like movements of immense quantities of money around the globe are incalculable, yet already they have clearly produced new kinds of political blockage and also new and unrepresentable symptoms in late-capitalist everyday life. (Jameson, 1997: 252)

Here, the parology that Lyotard first identified as the driving force of Post-Modern science becomes the effective mode of financial transaction. The statements of finance (i.e. - transactions), like the statements of scientific language games, are self-referential. To the extent that they refer to an external entity, they do so by recursively referencing the previously established statements and axioms of their particular game.

Likewise, their value lies in their ability to contradict previous statements and norms, without themselves being contradicted. A transactional algorithm, for example, might scan the market for undervalued entities; upon finding a discrepancy between the traded value of a particular entity and the value derived from its own algorithm, the trading algorithm will produce a statement-transaction in the form of purchasing or selling a given number of these target entities[12] (or by constructing derivative options or other tradable products based on the value discrepancy). This statement-transaction affects the value of the entity to which it refers. Like the statements made in law or programming code, it is operational—what is stated becomes fact by virtue of its being declared.[13] In doing this the transactional entity is functioning as a value conduit—it retains (or loses) the differential between the values of the target entity: there is an *excess* or *surplus* in the relations of equivalence which the algorithm has been programmed to extract. At least metaphorically, the system runs on this excess charge or mismatch of the equivalency relation. However, physically, the system literally runs on an excess or *difference*—an electrical, material charge differential. Underlying the relations of equivalency are the + and the – , which are the conditions for its spatio-temporal operation.

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[12] This is, of course, an automated, concretized version of how a human trader would historically operate. However, the condition of parology arises from the speed, complexity and unintended consequences of these decision making entities as they become increasingly interlinked and sophisticated.

[13] To again use the language of Virno, "mental abstractions are immediately, in themselves, real abstractions," and "thought becomes the primary source for the production of wealth." Here the mental decision-making operations have been embodied in a technological mechanism.

The specific consequences of such exchange events are increasingly interlinked, complex and difficult to predict—or indeed to comprehend. More so than before, the abstraction "precedes thought". In fact it generally does not even come into contact with thought, with the exception of the financial workers whose role is to form the necessary human conduit for the system—even as this system is moving towards increasing automation[14].

> […]finance capital brings into being: a play of monetary entities that need neither production (as capital does) nor consumption (as money does), which supremely, like cyberspace, can live on their own internal metabolisms and circulate without any reference to an older type of content. (Jameson, 1997: 265)

Given the complexity and speed of transactions, new tools for analysis are required.[15] At the same time that these new mechanisms are developed, they likewise become operative abstractions within the system—they become factual entities with real effects. To the extent that any mechanism becomes widespread, other financial algorithms and decision-making systems will have to account for it within their own analyses. The subroutines and mechanisms of these systems are contingent and co-dependent, they form an interlinked environment in which the procedures or fragments of multiple programs may coalesce to produce stable, or emergent entities—entities that are in every way material and that have concrete effects. The parameters of what constitutes a "real" entity require reconsideration.

These trading algorithms and decision-making systems are, of course, at some point in their production, the design of financial and computer engineers. However, given advances in the field of programming such as evolutionary computation (which involves programs that can design, "evolve" and optimize other programs or algorithms) it seems inevitable that these and other developments will find their way into the financial sector. Just as the development of digital networks began first with academic and scientific research before becoming a medium of finance, it seems a reasonable speculation to say that the greatest advances in "artificial intelligence" or computational intelligence in the coming years will likely be geared towards financial operations.

As automated, financial decision-making entities proliferate and increase in sophistication, a decision-system that has the ability to anticipate the decision-making process of a competing decision-system will be highly successful within the overall paradigm. Such decision-entities would have to be able to incorporate a model of the competing systems into their own operation. Theoretically, a

[14] In 2013, for example, an estimated 65% of all trades were automated—up from approximately 25% in 2004.

[15] For example, spectrum analysis, analyzes the multitude of financial data as frequencies or wave patterns that can be viewed in cross section, or searched for emergent patterns.

decision-entity that that can account for its own existence, as well as the existence of similar decision-making entities (which may utilize deception algorithms, for example) within its operations would have an unprecedented advantage.

The potential financial benefits of a program or system that can quickly learn from mistakes and respond flexibly to new information-events in the financial markets would far outweigh the financial benefits of automating production processes. The promise of automation to free up labor-time and enrich society has instead been replaced by a new category of "intellectual" or "performative" labor, while the higher-level administration of the economy is itself moving towards complete automation. This set of conditions will likely be the main economic driving force behind the development of "artificial intelligence" or computing intelligence technology, and it gives new import to Marx's Hegelian inversion: "the movement of capital qua substance becoming subject."

Regardless of the level of measureable self-awareness that is achieved by financial decision-entities, what is almost certain is that their decision-making processes will become increasingly opaque, paradoxical and unfathomable (though no less verifiable). The pronouncements—the factual outputs—of these systems are already beyond any common comprehension and have taken on an axiomatic form[16]. However, this concrete stream of facts is the outcome—the continual cycling through—of the ramifications of abstract value exponentially acting upon abstract value. What began in equivalency ends in the unrepresentable.

[16] To use a term that Deleuze and Guattari have applied to the undifferentiated character of capital, more generally.

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