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**A Summary Outline of**

**"AGGREGATIVITY: REDUCTIVE HEURISTICS FOR FINDING EMERGENCE"[1]**

~ Dr. William Wimsatt[2]

Thesis Statement
(This is what I understand the article to be stating in one sentence):

The whole is more than the sum of its parts, but it is in knowing the parts and the relationship between the parts, that the whole is better understood.

## I. Prolegomena:

### A. Important Terms to Know:

1. **Aggregativity**: To come together, or bring different things together, into total, mass, or whole; sum-total, forming a total. Wimsatt defines aggregativity this way, "***the non-emergence of a system property relative to properties of its parts***" or "***the whole is nothing more than the sum of its parts***" (372).

2. **Amplification Ratio**: Is the increase in the magnitude of a signal produced by an amplifier (Encarta).

[1] "Aggregativity: Reductive Heuristics for Finding Emergence," William Wimsatt, Philosophy of Science, 64 (Proceedings) S372-S384, 1997.

[2] William Wimsatt is Professor of Philosophy and is a member of the Committee on Evolutionary Biology and the Committee on the Conceptual Foundations of Science. He studied engineering, physics, and philosophy at Cornell, earning a B.A. in 1965. He received the Ph.D. from the University of Pittsburgh in 1971 and began working at the University of Chicago in the same year. Wimsatt teaches in the Biology Collegiate Division (undergraduate), the Committee on Conceptual Foundations of Science (graduate), the Program in History, Philosophy, and Social Studies of Science (undergraduate), the Committee on Evolutionary Biology (graduate), the M. A. Program in the Social Sciences (graduate), and, of course, the Department of Philosophy (graduate and undergraduate). His work centers on the philosophy of the inexact sciences—biology, psychology, and the social sciences—the history of biology, and the study of complex systems. www.UChicago.edu

3. **Compositional Sciences**: Combining simply objects into one object (e.g., chemistry is a composition science that examines the makeup of a particular portion of a substance; computer science combines types and subroutines into more complex ones; geology examines the crystal structure of a substance).

4. **Connectionist modeling**: an approach found in neuroscience, philosophy of mind, artificial intelligence, and cognitive science that considers "*mental or behavioral phenomena as the emergent processes of interconnect networks of simple units*" that utilize neural network models [Meta-Encyclopedia of Philosophy].

5. **Decomposition**: reduction of or breaking down of a property into pieces or constituent parts.

6. **Deduction**: The process of deriving statements (conclusion) that follow necessarily from an initial set of statements [*Philosophy of Science*, 776].

7. **Emergence**: The act or process of coming out, appearing, or coming about. Philosophically, emergence may be stated this way. It is a system that exhibits emergent properties when those properties **are more** than the sum of its parts' properties (e.g., mental properties that emerge from physical properties of a mind). Wimsatt states that "*an emergent property is- roughly-a system property which is dependent upon the mode of organization of the system's parts*" (372). Wimsatt later states that *emergence involves some kind of organizational interdependence of diverse parts, but there are many possible forms of such interaction, and no clear way to classify them* (375)."

8. **Heuristics** (Gr. *heuriskein*, "*to discover*"): "Serving to find out, helping to show how the qualities and relations of objects are to be sought" [*Meta-Encyclopedia of Philosophy*]. In the field of computer science heuristics is a technique designed to solve a problem that ignores whether the solution can be proven to be correct, but which usually produces a good solution or solves a simpler problem that contains or intersects with the solution of the more complex problem. Interestingly, in continental philosophy, heuristics, is used when an entity A exists to enable understanding of or gain knowledge of entity B [Wikipedia].

9. **Multiple-Realizability:** This theory contends that a single mental kind (property, state, event) can be realized by many distinct physical kinds. E.g., pain: a wide variety of physical properties, states, or events, sharing no features in common at that level of description, can all realize the same pain [*Meta-Encyclopedia of Philosophy*].

10. **Physicalism:** An ontological doctrine that holds that the world is entirely composed of physical phenomena. Physicalism is often understood as the stronger, reductionist thesis that the world can be entirely described in the vocabulary of physics [*Philosophy of Science*, 779].

## B. Summary of Article:

### 1. Reduction and Emergence: *Can't we all be right?*

He begins his paper by discussing reductionism vs. emergence. Those who adhere to emergence believe that the whole is more than the sum of its parts (e.g., traffic jams; its always turns out to be more than you thought it to be ☺). On the other hand, reductionists believe that the whole is merely the sum of its parts. Wimsatt suggests that maybe we don't have much of a battle between these two notions as we are led to believe simply because reductionism can sometimes better explain emergence. In other words, why can't we use the results of reductionism to better explain emergence (373)? To be sure, a reductive analysis of emergence doesn't satisfy some philosophers; they want more. For example, emergent philosophers want to reject all of reduction but it is because they use a very limited deductivist notion of reduction. But Wimsatt does not agree with that notion or the use of multiple-realizability as the alternative. Rather, Wimsatt believes that reductionism is more compatible with multiple-realizability than is widely assumed. He is confident that the scientists in the complex sciences would agree.

Much of the article is given to various methods of decomposition (e.g., the rearrangement of the properties of the system; the rearrangement of the properties of the properties themselves; the rearrangement of the actual system). The method of decomposition used for a particular system will reveal details of the system's organization. In essence, we shouldn't rule out reduction because decomposition is not possible at one level. Rather, we should see its failure as informative, revealing aspects of the mode of organization of the parts of the system. This should please any anti-reductionist. Why?--Because the antireductionist is concerned with the organization of the individual parts in its current state. In other words, by placing different levels of decomposition onto the system, weaknesses in the system are not the goal. Rather, strengths of its organization come to the surface. In fact, the upshot is that more cases of "*pure*" emergence aka, glorified ignorance, can be dispelled and exchanged for a more focus discussion.

In sum, Wimsatt is not against emergence if it goes hand-in-hand with reductionism; use reductionism to explain emergence.

## 2. Conditions of Aggregativity:

A. Aggregativity:

1. Definition of aggregativity: "*the non-emergence of a system property relative to properties of its parts*" (375).

2. For each condition the system property must remain unchanged. In fact, the system property is independent of variations in that kind of relationship (property) among the parts and their properties.

3. Aggregative properties depend on the parts' properties in a very strongly atomistic manner (remember: atomism is the idea that atoms make up everything) under all physically possible decompositions.

4. It is extremely rare that all of these conditions are met. In fact, aggregative conditions should be noted in terms of being the complete opposite of functional organization (I am assuming what he means by functional organization is the ability to perform smoothly) (375).

a. Post-Newtonian science (i.e., first order corrections of general relativity) has concentrated has concentrated disproportionately upon such properties and studying them under “well-behaved” conditions. He believes that these “aggregative” properties have been “substantially exaggerated (376).

5. These are the properties that will satisfy aggregativity (i.e., these are conditions that must be met and even though strong satisfaction is rare, this is the grid to use which Wimsatt believes is sufficient for aggregativity).

B. The conditions that treat how the system property is influenced are four-fold (376):

1. **IS** InterSubstitution or Rearrangement of Parts: Invariance of the system proper under operations rearranging the parts in the system or interchanging any number of parts with a corresponding numbers of parts from a relevant equivalence class of parts.

| Can you rearrange the parts in a system or interchange them and continue to maintain your whole? |
|---|

2. **QS** (size scaling) Qualitative Similarity of the system property (identity, or if it is a quantitative property, differing only in value) under addition or subtraction of parts (This suggests inductive definition of a class of compositional functions).

| Are there properties added or subtracted? |
|---|

3. **RA** (Decomposition and ReAggregation) Invariance of the system property under operations involving decomposition and reaggregation of parts (This suggests an *associative* composition function).

| Can the system be put back together? Can it be broken down (decomposition) and reaggregated (put together) any way. |
|---|

4. **CI** (Linearity) There are no Cooperative or Inhibitory interactions among the parts of the system for this property.

| No parts of the system are mutually dependent. |
|---|

*“For a system property to be an aggregate with respect to a decomposition of the system into parts and their properties, the following conditions must be met” (376).*

C. My example using Legos: A Failed Test of Aggregativity:

Legos: I have a claim that an airplane made of legos satisfies three out of our aggregative conditions (as opposed to the human body which is clearly not aggregative because it would die in the process of decomposition).

An airplane is an emergent structure in that it has a certain method of organization. If the blocks were placed randomly together another structure could be formed that does not closely resemble an airplane; the organization of the parts is employed. But let's not ignore the fact that it is simply a collection of similar blocks that can be broken down, meeting the conditions of aggregativity; you can destroy and reassemble it an unlimited amount of times into the same structure (i.e., the airplane). The emergent may say "I can also make into a boat or a rocket." But the reductionist will always say, "Yes, you can, and even more depending upon how well you know its individual parts. Wimsatt would say that is why you would need both emergence and reductionism; both are right, for emergence can be explained better through reductionist approaches.

With the airplane, I've satisfied all three out of four conditions:

1. I've satisfied InnerSubstitution. When you are tear down or put together an airplane of Legos (each block being its own property), it can be put together successfully each time-even if different blocks are used.

2. I've also satisfied QS (Qualitative Similarity).

   If increased in size or reduced in size (properties added or subtracted) the whole, with its individual properties, are maintained. See, you still have your lego structure. We are not asking it to be exactly the same-but it is to be similar to what we have added or subtracted.

3. I failed to satisfy RA (ReAggeration).You can't effectively tear the lego plane apart and rebuild it anyway you would like, using each block in the exact same place. Thus, I failed to satisfy ReAggeration (RA).

   This particular condition is a very tough one to pass.

4. Lastly, the integrity of each part (lego building block) is not dependent on another one, thus satisfying Cooperative or Inhibitory condition (CI).

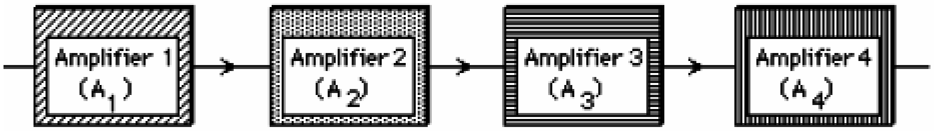
Beware: Let's suppose the plane is fully aggregative and we decide to apply a different level of decomposition to the legos; let's melt the legos down to plastic "soup." Though the mass has remained unchanged we know longer have individual parts with their own identity. Thus, we have failed conditions for aggregativity at this level of decomposition (i.e.,IS; RA). Yet what comes to surface from this experiment is that these blocks are largely dependent on the structural integrity of each of its parts (each and every lego). So, if you apply heat and modify its structural integrity, it can no longer meet conditions of aggregativity.

Therefore, let's be more inclusive in the type of reductionism we apply to systems; be heuristic-minded.

D. Wimsatt's example using Circuitry (idealized linear unbounded amplifiers) is fully aggregated:[3]

[3] Figure 1 is taken from William Wimsatt, "Emergence as Non-Aggregativity and the Biases of Reductionisms" Committee on Evolutionary Biology, and Committee on the Conceptual Foundations of Science, University of Chicago, v. 67: November 2003, 28 pages.

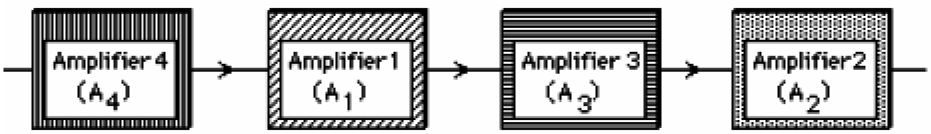
Figure 1: Conditions of Aggregativity illustrated with idealized linear unbounded amplifiers.




1a: Total Amplification Ratio, At, is the product of the amplification ratios of the individual amplifiers: At = A1 x A2 x A3 x A4.

In figure 1a we have an aggregate system.

### 1st CONDITION—IS: CAN YOU REARRANGE OR INTERCHANGE THE PARTS IN A SYSTEM AND CONTINUE TO MAINTAIN THE WHOLE?

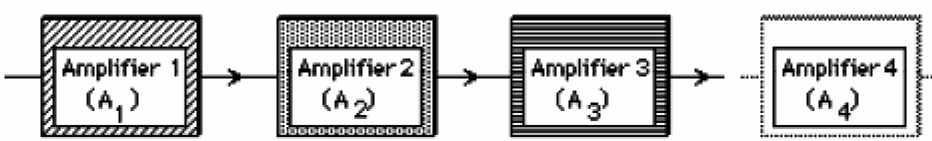



1b: Total Amplification ratio, At = A4 x A1 x A3 x A2 remains unchanged over intersubstitutions changing the order of the amplifiers (or commutation of the A's in the composition function).

In figure 1b we are able to interchange the properties and still continue to maintain a whole; so in figure 1 **we have Rearrangement of Parts by changing the order and still we have an aggregate system; IS condition is satisfied.**

**IS** InterSubstitution or Rearrangement of Parts: Invariance of the system proper under operations rearranging the parts in the system or interchanging any number of parts with a corresponding numbers of parts from a relevant equivalence class of parts.

### 2nd CONDITION—QS: CAN YOU ADD OR SUBSTRACT A PART AND STILL MAINTAIN A QUALITATIVE SIMILAR SYSTEM?

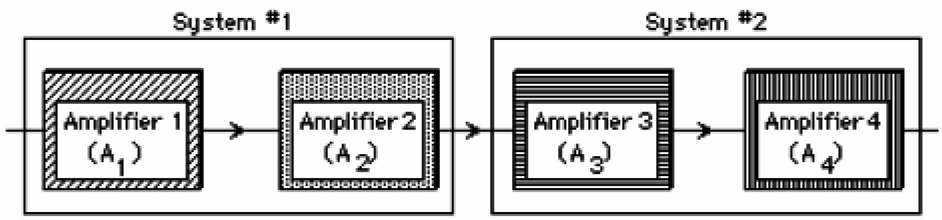



1c: Total Amplification Ratio, At(n) = At(n-1) x A(n), remains qualitatively similar when adding or subtracting parts.

In figure 1 c we have subtracted amplifier 4 from the circuitry but are still able to satisfy the qualitative similarity condition. **Even though we subtracted amplifier 4 the system qualitatively remained the same. QS condition is satisfied.**

**QS** (size scaling) Qualitative Similarity of the system property (identity, or if it is a quantitative property, differing only in value) under addition or subtraction of parts (This suggests inductive definition of a class of compositional functions).

### 3rd CONDITION—RA: CAN THE SYSTEM BE BROKEN DOWN (DECOMPOSITION) AND BE PUT TOGETHER AGAIN (REAGGREGATION)?

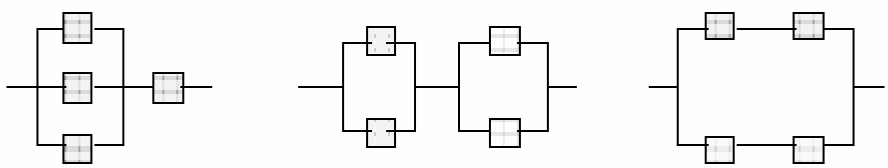



1d: Total Amplification Ratio is invariant under subsystem aggregation—it is associative: A1 x A2 x A3 x A4 = (A1 x A2) x (A3 x A4).

In figure 1d we are able to break down figure 1a into two systems (decomposition) and put them back together (reaggregation). RA condition is satisfied

**RA** (Decomposition and ReAggregation) Invariance of the system property under operations involving decomposition and reaggregation of parts (This suggests an *associative* composition function).

### 4th CONDITION--CI: NO PARTS ARE MUTUALLY DEPENDENT:



1e: The intersubstitutions of 1a - 1d which all preserve a strict serial organization of the amplifiers hide the real organization dependence of the Total Amplification Ratio. This can be seen in the rearrangements of 4 components into series-parallel networks. Assume each box in each circuit has a different amplification ratio. Then to preserve the A.R, the boxes can be interchanged only within organizationally defined equivalence classes defined by crosshatch patterns. Interestingly, these classes can often be aggregated as larger components, as in these cases, where whole clusters with similar patterns can be permuted, as long as they are moved as a cluster. (See Wimsatt, 1986.)

In figure 1e **CI** (Linearity) There are no Cooperative or Inhibitory interactions among the parts of the system for this property.

No parts of the system are mutually dependent; they are able to maintain individuality. Thus we are able to satisfy the CI condition.

## 3. The Benefit of Aggregative Properties:

A. We have to use constraints and be consistent with them. In other words, we cannot be blind to assumed constraints. If we are not assuming that we are not melting down the legos, we need to state that. By doing so, we have explained our limited aggregativity.

B. What we don't have is unqualified aggregativity (i.e., you break down the lego airplane and rebuild it anyway you desire; this is false).

C. Mass, energy, momentum, and net charge are aggregative without qualification, i.e., they remain invariant under any and all decomposition (e.g.., steer in the butcher shop) as opposed to volume which can inconsistently change because of chemical reactions). This doesn't give emergent something to smile about because it is showing that the whole is less than the sum of its parts. So, a lack of aggregativity does not necessarily prove emergence to be the explanation (381).

1. The more you can decompose something the more "*natural*" the results. In other words, we find valuable information by singling out the invariances in reduction. Those invariances then become the aggregative building blocks for emergence.

E.g., Let's suppose, once again, that the lego airplane did meet all four conditions of aggregativity, I can decompose the lego airplane in variety of ways. I can pull the legos off piece-by-piece, drop it on the floor, or smash it with tack hammer because all are permissible disruptions. Because we have qualified its aggregativity we will not further disrupt this invariant block; we have its basic property for building an airplane or other structures. This is the essence of reductionist problem-solving heuristics. Remember, we already constrained or limited its aggregativity by not changing the structural integrity of the building blocks themselves. In other words, you have to know when to stop; you have to recognize its variant.

**4. Aggregativity: Vulgar Reductionism, and Detecting Organizational Properties.**

A. Now, what are we going to do with these aggregative properties? The application of aggregativity or partial aggregativity will impact the method of reduction that is applied.

B. Very few system properties are aggregative, thus opening the door for emergence. It is sufficient for us to focus on the cases that are aggregative. I, Paul, wonder if Wimsatt is satisfied on just the few remaining cases because they will further explain the emergent cases.

C. Will supposed cases of emergence disappear as we come to know more? No! Rather, there are basic independent models which are more aggregative but as they grow they become more dependent on organization: the simple leads to ***explained*** emergence. In other words, the lesser will explain the greater. So, this reductionism vs. emergence debate is really a big misunderstanding.

D. All of a sudden, Wimsatt introduces the impact of realism on these simple building block models causing them to become more dependent on organization aka. emergent (382).

E. The higher degree of aggregativity (i.e., the less constraints we put on it) the more natural the results (i.e., the decompositions, the parts, and the properties). (382).

*"These are then particularly revealing cuts on nature" (382).*

F. If aggregativity connects closely with natural properties we understand the temptations of vulgar reductionisms. We are better on our guard against the fallacies of vulgar reductionism. These are considered to be "the nothing but isms [statements] and their siblings" (382). For example:

1. Genes are the only units of selection (383);
2. The mind is nothing but neural activity (383);
3. Social behavior is nothing more than the actions of individuals (383).

***Vulgar reductionism is ruling out too many factors and focusing too strongly on decomposition.***

*E.g., If I said that genes are the only building units of selection, then I have placed such superiority on the genes that no other part can be introduced into my model, and if do, it will be seen as a lesser part. So, whatever system is built is solely due to the organization of one part (i.e., the genes) becoming exponentially greater which is emergence in its greatest form (organization dependent). In other words, you can become so obsessive about a preferred decomposition that it becomes an emergent system.*

G. If you have committed vulgar reductionism then you will easily lose sight of the relations between the system properties and the parts' properties by focusing too strongly on choosing a decomposition and the broader effects of that choice.

In conclusion, aggregativity provides us with excellent tools known as invariant claims. They will better explain structures that are built upon them as well as the residual variant (i.e., things that don't fit; they are the ones that change or don't fit into the model well) and the explanation for those lie in the study of the invariant properties. Yes, the whole is more than the sum of its parts, but it is in knowing the parts and the relationships between them that the whole is better understood.