GST 100 — An Explanation of Emergence

Formal Description

Emergence is often described as a whole having a property or ability that its parts lack. Causal Assembly Theory makes this idea more specific. It asks what transfer the whole can produce or accept, which interactions enable it and how the assembly maintains those interactions between occasions of use.

As GST 99 explained, the criterion is a maintained causal capability that depends upon the assembly's organisation and is unavailable to its components acting separately. The same outcome might sometimes occur when separate entities happen to interact in the right order. What the assembly maintains is the capability to produce or accept the transfer under suitable conditions.

By the end, the learner should be able to trace an emergent capability through a sequence of interactions and propose a test of whether the capability depends upon the maintained organisation.

Plain English Explanation

Imagine a small processing unit containing two catalysts. The first helps convert an incoming material into an intermediate. The second helps convert that intermediate into a final product. The unit releases the final product through its outlet. This is a simplified example: the letters X, Y and Z stand for the incoming material, intermediate and product.

The first stage can make Y from X, but it cannot carry out the second transformation. The second can make Z from Y, but it cannot make Y from X. The connected unit can receive X and deliver Z because the output of the first stage reaches the second. Its channels and retained catalysts keep that pathway available between uses.

If the catalysts were dispersed, Y might still reach the second catalyst by chance and some Z might be produced. One observation of Z therefore does not establish a maintained capability. Nor is greater reliability by itself an explanation. We need to show which maintained relationships enable the unit to accept X and deliver Z.

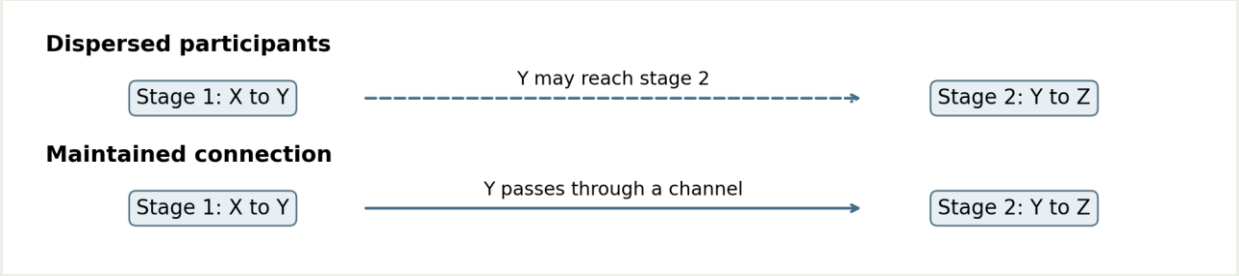
What a boundary can Contribute

Consider a hypothetical network of reactions that collectively help replenish their own catalysts. This is an example of autocatalysis. If the participants disperse, they may still encounter one another, but their products may diffuse away before reaching the next reaction.

A physical boundary or membrane that retains participants can help sustain the sequence, provided needed inputs can enter and substances that inhibit the reactions can leave or be removed.

Retention alone is insufficient. If the reactions also supply material that repairs or renews the boundary, then the boundary helps maintain the reactions and the reactions help maintain the boundary. This is a possible arrangement, not a requirement for emergence.

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The difference is whether the relationship that delivers Y to stage 2 is maintained between uses.

Examples

To identify an emergent capability, ask what the system can accept or deliver that its components cannot accept or deliver independently. Then ask which relationships make that possible.

Accepting an input: a bridge takes a load. A truss bridge can take the load of a vehicle midway across a span that none of its individual members is long enough to cross. The deck receives the load, and the connected members transmit it to the supports. The capability is to accept a load at that position across the span. It depends on how the deck and members are joined and remains available between vehicles.

Delivering an output: a battery pack supplies a higher voltage. Each cell in a battery pack can supply electrical energy. When cells are connected in series, their voltages add, so the pack can supply electrical energy at a voltage that no cell can deliver on its own. The capability is to deliver power at that higher voltage. The connections keep it available even when nothing is drawing power.

Accepting an input: an animal takes up oxygen from the air. In a mammal, breathing brings air into the lungs, while the heart pumps blood through tiny vessels close to the air spaces. Oxygen passes from the air into the blood and is carried to the tissues. The lungs alone cannot circulate the blood, and the heart alone cannot take up oxygen from the air. Their connected activity enables the animal to accept oxygen from the air as an input to its circulating blood.

Delivering an output: a flood response team evacuates residents. A boat crew can reach people cut off by floodwater, while a land crew can move people from the landing point to a shelter. By sharing information and arranging a handover, the crews can deliver residents from flooded homes to a place of safety. In this example, the boat cannot reach the shelter and the land crew cannot reach the homes. The complete transfer is an output of the organised response. The crews can keep that capability available between call-outs by maintaining their communications and handover arrangements.

An emergent property is a characteristic of the system as a whole. In these examples, that characteristic describes what an organised process enables the system to do: take a load across a span, supply power at a higher voltage, take up oxygen from the air into circulating blood, or deliver stranded residents to safety. The property describes a capability that the system retains between occasions of use. The process shows how that capability is realised when the relevant inputs and conditions are present.

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Provenance and Links

Foundational Causality traces the transfers linking processes. *Causal Assembly Theory: Assembly and Disassembly as Causal Processes* applies this account to emergence, distinguishing an occasional outcome from a capability sustained by organisation. The processing unit, bounded reaction network, bridge, battery pack, oxygenation of the bloodstream, and flood response team are teaching examples.

Challoner, J. A. (2026a). Foundational causality. Rational Understanding. https://rational-understanding.com/efgst/

Challoner, J. A. (2026b). Causal assembly theory: Assembly and disassembly as causal processes. Rational Understanding. https://rational-understanding.com/efgst/

Practical Exercise

Recall the processing unit with two stages. The first stage receives material **X** and converts it into **Y**. The second stage receives **Y** and converts it into **Z**, which leaves the unit as its final output. A channel carries Y from the first stage to the second.

1. **Identify the emergent property.** What can the whole unit do that neither stage can do independently? In your answer, name the input the unit accepts, the output it delivers and the transfer that connects the two stages.
2. **Predict what would happen if the connection were interrupted.** Imagine diverting Y before it reaches the second stage, while keeping the supply of X and other operating conditions the same. Would the first stage still produce Y? Once any Y already in the second stage has been used up, would the unit still deliver Z? How could you check that the second stage still works?
3. **Restore the connection and interpret the result.** If the unit delivers Z again once Y can pass between the stages, what does that tell you about the role of the channel? If the unit continues to deliver Z even after the original supply of Y has been used up, what other route might Y be taking?

Finish by explaining, in one or two sentences, how the unit's organisation allows it to accept X and deliver Z. This connects the **emergent property**, i.e., what the whole unit can do, to the **process** that makes it possible.

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