Here I will demystify “emergence” and make it utterly concrete.

Most people, if they think about it at all, regard emergence as a vague, “woo-woo” concept that philosophers and mystics deal in.

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If you attempt to read this Wikipedia article on emergence and you’re like me, your reaction is probably going to be: “Good grief!” https://en.wikipedia.org/wiki/Emergence

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So I’m here now to tell you this:

Anything in your experience that you can reasonably call a “thing” is a manifestation of emergence. (I’ll call that thing an “emergent”.)

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I’ll state below both an informal and a formal definition of emergence. They’re very similar, but the formal definition uses specific words so that you can make an example comply with it by substituting the words.

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Here is the informal definition.

Emergence shows up when a bunch of *individual things* are grouped together, and the grouping itself reveals *a new property* that the individual things don't reveal. We'll call that new property the "emergent".

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Examples:
A family is an emergent.

Public health: When a lot of people with communicable infections come together and an epidemic emerges, the epidemic is the emergent. The "individual things" are the sick people.

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The epidemic is a thing with its own properties, logically distinct from a bunch of sick people.

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We've also seen the term "herd immunity" used in public health; that's an emergent, too, but trickier. In this case, the individual *immunities* are the "individual things". The "new property" is this phenomenon: the epidemic doesn't grow.

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Note that what flips the epidemic from growing to not growing is a change in *interactions*. The flip occurs when the number of non-pathogen-transmitting people increases to the point that pathogen-transmitting people are not close to vulnerable people.

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Here's a different kind of example. Here we don't experience the individual things because they're too small.

The *substance* water is an emergent. The individual things are H2O molecules. The emergent is what we experience as a liquid, a solid, or a gas.

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There are two takeaways from these examples.
1. Emergence is a tricky concept and needs to be used carefully.
2. But it shows up in a lot of places.

My message here: it shows up *everywhere*.

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Here's the formal definition.
Emergence is a process that manifests phenomena at a higher level of aggregation that arise from *a pattern of interactions* among/between entities at a lower level of aggregation.

Note nine different concepts here:

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1. *Emergence* is a process,
2. There are *two levels* of aggregation,
3. The things at the lower level of aggregation we call *entities*,
4. At the upper level of aggregation are *collections* of entities (we sometimes call them *aggregates*),

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5. Sometimes (not always) we might speak of entities at the lower level of aggregation manifesting *phenomena*,
6. We speak of phenomena manifested by upper-level aggregates,
7. There are *interactions* among/between some lower-level entities,

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8. We identify *patterns* formed by some of these lower-level interactions, and
9. We identify one or more *emergents* as upper-level phenomena resulting directly from these lower-level patterns.

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Note that we might have completely different language describing the upper level and the lower level. This occurs in the water example cited above. That's why the word "description" occurs in the following diagram.

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Note also that there might be different kinds of aggregates of the same set of entities. That's why we use "an" and not "the" to modify "upper level" and "lower level".

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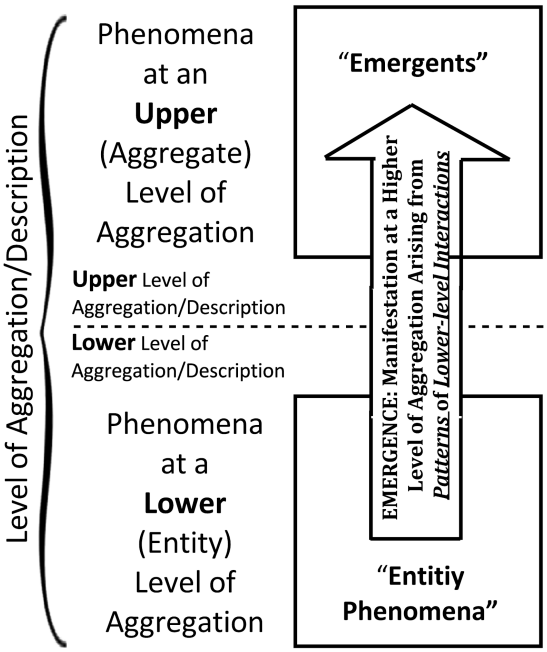
Here is a diagram depicting the definition.

Note to philosophers: It's emergents all the way down.



Emergents are Phenomena at the Upper, Aggregate, Level That Arise from *Patterns of Interactions* of Lower-level Entities

Mel Conway, 2020-2021

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<begin comment 1>
"Pattern of interactions" is a strange concept.
1. Many simple descriptions of phenomena recognize entities but ignore interactions. If they do recognize interactions at all, the interactions are secondary; the entities are primary.

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2. Even once entities and interactions are brought to the same level of importance, the idea of “patterns of interactions” is still strange. But these are exactly what make emergence happen. I also think it’s what has made the concept strange and difficult.

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3. “Duality” is a trick known to physicists and electrical engineers that reverses the concepts of entity and interaction (mutatis mutandis), while the principles remain invariant. It might be interesting to try it here.
https://en.wikipedia.org/wiki/Duality_(electrical_circuits)
(end comment 1>

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Here are a couple of examples that apply the formal definition.

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Military unit cohesion.
The Hoplite phalanx armor wall is an emergent.
Entities: The shields.
Interactions: The nesting of each shield with *only* its immediate neighbor.
Patterns: Every interior soldier on the front line does the same thing.
https://en.wikipedia.org/wiki/Hoplite

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Flocks of birds.
Entities: Starlings.
Interactions: Maintaining an optimum spatial relationship with six or seven *closest* neighbors (see article).
Patterns: All interior birds do the same thing.
https://www.npr.org/sections/13.7/2017/01/04/506400719/video-swooping-starlings-in-murmuration

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<begin comment 2>
Q: Why bother with this formalization?
A: Science. Once a particular system is modeled as an emergent, there is a (nearly) isomorphic design pattern for an agent-based simulator that will execute its behavior.

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Because these systems are complicated and often grossly nonlinear, they cannot be modeled analytically. Simulation is used to gain insight in order to improve a model. Thus we have a process for self-improvement.

This is the beginning of science.

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It's also a good reason to bring together people (who otherwise wouldn't be talking with each other) into new kinds of multidisciplinary research teams. In my view this is the only way we will begin to understand our big-system problems.
<end comment 2>

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This essay is part of the "Emergence" section of this theory:
https://twitter.com/conways_law/status/1354871192025526276

cc:

@mfeathers @PezeshkiCharles @fluffbuster @pauldunscomb

Others: let me know of your interest and I'll add you to the list.