The Architecture of Complexity

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General systems theory: taking things in common from physical, social and biological systems to find properties in common.

Cybernetics: The study of the communication and control systems in a mechanical or electrical thing, and also the study of the same in biological systems.

I think this paper is a position paper on cybernetics as of 1962, but given where it is published (a philosophical journal) it isn’t going to be too in depth. I hope.

“by a complex system I mean one made up of a large number of parts that interact in a non-simple way”

- **holism noun, the theory stating that a complex entity or system is more than merely the sum of its parts or elements. – Chamber’s dictionary.**
- **pragmatic adj concerned with what is practicable, expedient and convenient, rather than with theories and ideals; matter-of-fact; realistic. – Chamber’s dictionary.**

On the second page he says that complex systems are more than the sum of their parts in a very pragmatic sense. You can’t infer the whole from the parts.
He describes that there are 4 aspects of complexity:

- Hierarchy. A complex system is made of things which are complex and so on.
- Hierarchical structures evolve faster than non-heirarchical ones of the same size.
- Complex systems can be broken down into subsystems that can be analysed
- Complex systems and their descriptions are related??

Hierarchies are the architecture of complexity, is what this paper will argue.

Hierarchic systems

“by a hierarchic system, *or hierarchy, I mean a system that is composed of interrelated subsystems, each of the latter being, in turn, hierarchic in structure until we reach some lowest level of elementary subsystem.”*

Things we consider to be elementary particles aren’t actually elementary particles, eg atoms they’re usually complex systems. A cell is not elementary but built of all kinds of other crap. You should be careful calling something elementary when it is not (but is elementary enough for your needs).
The word hierarchy implies that a high level thing is the boss of its lower level parts but that is not really the case, there are no bosses the relationships are far more complicated.

This kind of structure, where complex systems are made of smaller complex systems is prevalent everywhere: space, the body, particles etc. in these kinds of system it varies enormously as to how many subsystems there are to a system. There can be loads or just a few. For example a cell has thousands of proteins and molecules stuff in them but these molecules only have a few atoms in them.
One way of describing a hierarchy is to define how the systems interact and the intensity of interaction. This can then apply to biological as well as social complex systems where you might naively think to define the hierarchy spatially. But defining it by interactions applies nicely to everything.

There is a section which is a story about 2 watchmakers. The moral of this story is that it is a lot easier to make something out of subsystems that to shove it all together at once. This fact probably gave complex systems a biological advantage and caused them to be prevalent because things which weren't constructed this way died off. Furthermore, the complex systems that are unstable do not survive, because growing indefinitely requires resources that are not present, so complex natural systems are stable. (Let's forget homeostasis and all that jazz for now).

teleology the doctrine that the universe, all phenomena and natural processes are directed towards a goal or are designed according to some purpose.

If a complex system absorbs energy then the system will have less entropy than its components (I'm not sure why), in biological systems this energy tend to come from the sun.

Next there are further musings on how breaking down the problem makes it easier. With research we explore many different paths, some of which are abandoned and some are followed further. The process of selecting which paths to take and abandon drastically cuts down on the amount of time spent working on the problem because we don't have to explore every single path, just the ones that have been selected as worthwhile. They are basically saying with this watchmaker analogy that:
"complex systems will evolve from simple systems much more rapidly if there are stable intermediate forms than if there are not".
This is why complex systems tend to be hierarchical. They are able to form from aggregates of these other, stable systems. If these stable systems can self-reproduce then they are likely to be more prevalent and so better able to come together to form something new.

On page 8 Simon talks about "nearly decomposable" systems. These are ones where a) in the short term the components of a subsystem are independent of components of other subsystems. B) in the long term each subsystem depends, in an aggregate way, on the other subsystems. They use an example of separate rooms in a building. A room is a subsystem. Each part of a room starts at a different temperature but the room reaches a temperature equilibrium quickly. The rooms in the building will all reach an equilibrium eventually, but it takes much longer that the individual rooms did.
Inside component subsystems of "nearly decomposable" systems there is more communication, and elements of the component work on a shorter time scale than communication and working between subsystems. I think this is the gist of what he spends several pages talking about.

The hierarchical structure of complex systems is something that helps us to understand them. If we saw something like a plant as a bunch of atoms (or whatever atoms are made of) shoved together then we wouldn't really be able to understand how it works because there are so many atoms and things interacting to make the plant that the problem is intractable. If we see the plant as a combination of leaves, flowers, stems and roots then we can understand how the things work together to make a plant.

Hierarchic systems are redundant:

- They are usually made of a few different types of subsystem, often repeated or combined differently.
- They are "nearly decomposable"
- (this one's a bit weird) you can re-express the system to show that there is redundancy. Their example is the sequence 1 3 5 7 9… each number is different but we can show the redundancy of the sequence by then just having 2 added each time.

State descriptions: describes something as it is eg "a square is regular quadrilateral". This is kind of a description of how the world is sensed.
Process descriptions: draw a line of x length then draw another, perpendicular one on its end repeat until box is formed.
State description describes something as it is. Process description describes how the thing is formed. Being able to tell the difference between the two is what makes an organism adaptive.
"the correlation between state description and process description is basic to the functioning of any adaptive organism, to its capacity for acting purposefully upon its environment."