Mike Joffe
(Imperial College London)

Causal links, systems and complexity:

Complexity is a property of certain types of system. This implies that the starting point for considering the relationship of complexity to causation ought to be the accurate characterisation of a system. This paper argues that systems should be seen as combinations of causal links, each one of which has a mechanism. For example, temperature regulation in mammals (a form of homeostasis) is achieved by various mechanisms, such as shivering and sweating; the homeostatic feedback system is not itself a mechanism, but is rather composed of links of this kind. This straightforward conception accords with usage in biology. Unfortunately, the early literature on mechanisms regarded them as *by definition* complex systems (Glennan), made up of component parts and operations (Bechtel & Abrahamsen), or entities and activities that are organised (Machamer et al). Mechanism was thus conflated with system properties or organisation. Although this has been weakened in recent years, the conflation has not completely disappeared. This is now manifest in the way that "organisation" is now used, e.g. by Illari and Williamson, to cover completely distinct phenomena: spatio-temporal relationships; which activities and entities are involved; system properties including homeostasis, equilibrium, feedback and self-organisation; and quantitative description and numerical simulation.

Seeing systems as composed of links makes sense of a number of observations. One is that some mechanisms are in fact very simple. There is some recognition of this in the recent literature, but two examples may make this clearer. The enzyme pepsin has a well-established mechanism, that cannot be broken down into distinct components – there is only the one link. It is based on spatio-temporal relationships plus additional factors such as electrical charge and polarity. Similarly, a clavichord is a simple mechanism that just has a "tangent" that strikes the string, connected directly to the key by a pivot ("balance pin") – unlike a piano, which has a complicated system of separate parts. Spatio-temporal relationships are again central. I regard these as single-link mechanisms.

When links combine, system properties may arise. These can include feedback effects etc, as well as complexity. Returning to the temperature regulation example, each component link has a mechanism that produces a phenomenon, e.g. shivering is muscular activity that generates heat; in addition to these *link-specific* phenomena one also observes a *system-level* phenomenon, that core temperature remains constant across a wide range of environmental conditions. The same observation applies to complexity, in some cases at least. For example, sand dunes show features of chaos, fractals and self-organisation (*system-level*) resulting from the separate mechanisms of erosion, deposition, vegetation, etc (*link-specific*). Again, each of the latter mechanisms produces its own phenomenon, pertaining to that causal link, and in addition one observes an overall system-level phenomenon, in this instance with features of complexity.

But links do not necessarily form into systems. The literature on mechanisms has paid little attention to this issue: the predominant practice has been to select a particular example – a synapse, or some aspect of neurophysiology – and then to subject it to philosophical analysis, without first considering how it comes to have the specific features that it has. Because most of the chosen examples have been drawn from physiological systems of various kinds, which have been perfected by evolution, the impression is given that mechanisms are necessarily tightly organised. The same can occur when a technological example is taken, such as a light switch – the product of design and therefore of human purpose (which is itself biologically evolved). These are examples of organised systems. Systems can also occur in the absence of evolution or purpose, as is the case with sand dunes: the co-existence of the different causal forces of wind, vegetation, etc, bring about the system-level properties. This can be characterised as a non-organised system. Other examples can be seen in ecology, e.g. predator-prey dynamics, or in economics as with markets tending towards equilibrium due to the operation of supply and demand mechanisms. What has been missing is rigorous attention to the *conditions of existence* of any system that is subjected to analysis; without such characterisation, the selected example fails to be located in its place in the world. The analysis is incomplete, disembodied.

There are limits to this bottom-up approach of seeing systems as combinations of causal links. For example in biology, whilst it has been successful in accounting for a wide variety of phenomena in relation to how organisms function, others have eluded this reductionist method. As a result, systems biology has been developed, which combines traditional biological methods with simulation and other quantitative methods. This involves non-linear systems, with effect modification, feedback and feed-forward loops, etc. These are still system properties built up out of constituent causal links, but with a higher degree of elaboration. Even so, the jury is still out whether this approach will be adequate for questions such as how cells and organelles develop and divide. It may be that such phenomena will continue to elude this reductionist approach. The reductionism is arguably not in the philosophical concept of a system made up of links being argued for here, but rather is a feature of the biological methods themselves.

In conclusion, mechanisms and systems are radically different. A mechanism is an aspect of a causal relationship, conceived of here as a single causal link. A system, on the other hand, is made up of a number of causal links. Some features that are typically ascribed to the organisation of a mechanism are retained in this conception, notably spatio-temporal relationships. In contrast, system properties (including homeostasis, equilibrium, feedback and self-organisation) are not – they are features of the way links combine into systems. Furthermore, the existence of a system cannot just be ignored or taken for granted; rather one needs to specify, as part of a philosophical analysis, the conditions of existence of any particular system. In some cases these arise from biological evolution or from human purpose ("organised" systems), but this is not necessarily the case.