GST 86 — Common Causal Structures

Formal Description

Causal networks can exhibit recurring patterns of causal organisation. Recognising these patterns allows complex causal reality to be represented in simplified forms that can be compared across otherwise very different phenomena. Within these course modules, such representations are described as causal structures.

A causal structure is therefore an epistemic representation of a recurring pattern of causal organisation recognised within causal networks. The represented structure should not be confused with the complete causal network itself. A network represented as linear for a particular purpose may form part of a much larger network containing branching, convergence, feedback and other structures.

Linear causality represents a single causal pathway connecting a cause and effect. **Branching causality**, or a causal tree, occurs when one cause gives rise to several effects through different pathways. **Converging causality**, or a causal root, occurs when several causal pathways contribute to a single effect. Convergence is particularly important where several necessary or enabling causal contributions combine at a recipient process.

Domino causality is sequential: each effect becomes a cause of the next effect in the sequence.

Cyclic causality occurs when a causal sequence repeatedly recreates the same *types* of causes and effects, although the particular entities involved need not be the same on each cycle.

Mutual causality occurs where two entities or processes causally influence one another. **Feedback** differs in that an output returns, directly or indirectly, as an input that influences subsequent operation of the process or system from which it arose. The return pathway may therefore contain additional causal processes.

Cascading causality occurs where each successive stage both continues a causal chain and contributes to a common accumulating effect. **Propagating causality** instead involves causal effects spreading through a connected network, initiating additional pathways as they spread.

Relational causality occurs where an effect depends upon a relationship or difference between states rather than upon either state considered independently. **Threshold causality** occurs where a causal effect or pathway becomes active only when a relevant variable reaches or crosses a particular value.

These structures are not mutually exclusive descriptions of whole causal networks. Several may coexist within the same network, and the structure recognised will depend partly upon the portion of causal reality selected and the granularity at which it is represented.

Plain English Explanation

We have already seen that causal reality is usually more complicated than:

A → B

Nevertheless, certain patterns occur repeatedly within complex causal networks. Learning to recognise them gives us a useful vocabulary for describing how causality is organised.

The simplest is linear:

A → B

One causal pathway connects the phenomena we are considering.

If A produces several effects, the pathway **branches**:

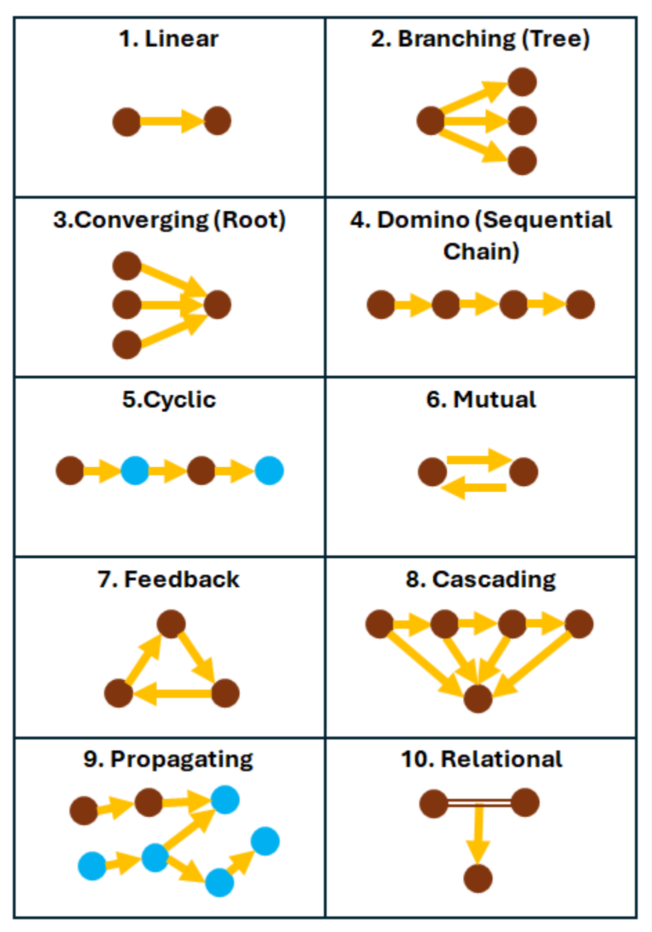
A → B, C and D

If several pathways instead contribute to D, they **converge**:
A, B and C → D
A **domino** structure extends the sequence:
A → B → C → D
Each effect becomes the cause of the next.
Cyclic causality is subtly different. A recurring causal pattern generates further instances of the same types of entity or event. A chicken produces an egg, from which another chicken develops, which may subsequently produce another egg. The individual chickens and eggs change, but the causal pattern recurs.
Mutual causality occurs when two processes influence one another:
A ⇄ B
A conversation is a simple example. Each person's behaviour influences the other's subsequent behaviour.
Feedback requires a causal pathway through which a consequence of a process eventually returns to influence its subsequent operation. A thermostat provides a familiar example: room temperature affects the thermostat; the thermostat influences heating; heating alters room temperature; and the changed temperature subsequently affects the thermostat again.
A **cascade** has another distinctive feature. Each stage continues the sequence but also adds to a common accumulating effect. Repeatedly borrowing money to meet previous repayment obligations can continue the borrowing sequence while progressively increasing total indebtedness.
Propagation is more like spreading. A failure in one part of an electricity network can alter loads elsewhere, causing additional failures and spreading the disturbance through the network. Unlike a cascade, there need not be one common accumulating effect.
Relational and threshold causality remind us that causal structures need not consist simply of one event pushing another. Heat flow depends upon a temperature difference between objects. Overflow occurs when water level crosses a threshold established by the containing edge.
Recognising these patterns can help us understand an unfamiliar causal network because we can ask:
“What kind of causal organisation am I looking at?”
But the classifications are analytical tools rather than boxes into which whole systems must fit. The same real-world causal network may contain several structures simultaneously.

Common Causal Structures

Recurring patterns within causal networks can be represented as simplified causal structures. Several structures may occur simultaneously within a larger causal network, and their recognition depends partly upon the boundary and granularity of analysis.

Students should use this figure initially as a **pattern-recognition aid**, then return to the physical causal interpretation developed in earlier modules by asking what processes and transfers would instantiate each structure.



Examples

A volcanic eruption illustrates branching causality because one eruption may contribute to lava flows, ash fall and atmospheric effects through different causal pathways.

River flooding can illustrate convergence. Heavy rainfall, saturated ground, elevated groundwater and restricted drainage may contribute through different pathways to the same flooding event. The necessary and enabling causal contributions considered in previous modules can therefore appear structurally as convergence.

A row of falling dominoes provides the literal example of domino causality. Each falling domino transfers energy to the next, which subsequently performs the same causal role in relation to its neighbour.

A conversation illustrates mutual causality, while a thermostat controlling heating illustrates feedback. The distinction is useful: mutual causality requires reciprocal influence between two

processes, whereas feedback involves consequences returning through a causal pathway to affect subsequent operation.
Increasing debt through repeated borrowing illustrates cascading causality because each borrowing episode both contributes to another stage and adds to the accumulating debt. Failure spreading through an interconnected electricity network instead illustrates propagation, because the defining feature is the expansion of the disturbance through the network.
Heat flowing between two objects illustrates relational causality because the direction and magnitude of heat transfer depend upon their temperature difference. Water overflowing a container illustrates threshold causality because a new causal pathway becomes active when the water level exceeds the height of the containing edge.

Provenance and Links

The recognition of recurring causal structures has antecedents across several intellectual traditions. Aristotle distinguished different forms of causal explanation, while much later work in science and philosophy increasingly recognised that causal relationships cannot always be adequately represented as simple linear sequences.
Norbert Wiener and the development of cybernetics made feedback particularly important to systems thinking by showing how the consequences of system behaviour can return as inputs and influence subsequent behaviour. Related work in control theory and system dynamics subsequently developed the analysis of feedback loops, delays and interacting causal pathways.
Network approaches and graphical causal analysis have further encouraged explicit representation of branching, convergence and indirect causation. Modern causal diagrams, including those associated with Judea Pearl, demonstrate how different causal configurations can have importantly different implications even where the same variables are involved.
Some terminology used in this module is more specific to the framework developed in these course modules. In particular, cascading causality is distinguished from propagating causality: cascading involves successive stages contributing to a common accumulating effect, whereas propagation is defined by causal influence spreading through a connected network.
The course also treats these causal structures explicitly as epistemic representations of recurring organisation within underlying physical causal networks, rather than as separate ontological forms of causality.

Practical Exercise – Student Response Area

Return to your developing causal representation of the town experiencing local flooding after heavy rainfall. Your task is now to identify recurring causal structures within that network rather than merely individual causal relationships.
Begin by finding the simplest linear relationship you can reasonably identify. Select two causally connected processes and represent the relevant portion as:
A → B
Remember that calling this relationship linear does not imply that the wider causal network is linear.
Next identify a **branching structure**. Heavy rainfall provides one possible starting point. Consider several different causal consequences that may arise from rainfall and draw the pathways through which the causal organisation branches.
Now identify a **converging structure**. Choose an effect such as increased river flow, high water level or property flooding and identify several causal pathways that may contribute to it. Compare these

converging pathways with the necessary, sufficient and enabling contributions you considered in previous modules.

Look next for a possible **domino sequence** in which successive effects become causes of subsequent effects. Explain why the sequence qualifies as domino causality rather than simply describing it as a causal chain.

Consider whether the flooding example contains **mutual or feedback causality**. Do not assume that it must. If you identify feedback, trace the complete return pathway and show how a consequence eventually influences the process from which it arose. If you cannot identify a credible example within your chosen boundary, explain why rather than inventing one.

Now consider **cascading and propagating causality**. Could successive events during a flood progressively contribute to a common accumulating effect, such as total damage? Could disruption instead spread through connected infrastructure, for example from flooded roads to traffic displacement and disruption elsewhere? Explain which structural description better fits each case and why.

Finally, identify a possible **threshold**. River-bank height, drainage capacity, doorway level or another physical threshold may be relevant. Explain what changes causally when the threshold is crossed. If appropriate, also identify a **relational cause**, such as a difference in water level that produces flow.

Annotate your developing causal network with the causal structures you have identified. Do not attempt to classify the network as a whole as one particular type. Instead, show how different recurring causal structures coexist within different portions of the same causal organisation.

In the next module, Persistent Causal Organisation, you will make another important change in perspective. Rather than concentrating only upon causal activity occurring during the flood, you will examine the persistent causal organisation within which those transient events become possible.

