GST 90 — From Causal Reality to Causal Knowledge

Formal Description

Causal reality exists independently of our knowledge of it. The processes, transfers, conditions, constraints and causal organisations through which effects occur are ontological, whereas observations, hypotheses, explanations and theories concerning them are epistemic representations. Causal knowledge therefore depends upon constructing and testing representations of portions of an independently existing causal reality.

An important starting point is the recognition of recurrence. When similar phenomena repeatedly occur together, or variation in one is consistently associated with variation in another, a potentially significant relationship may be recognised. Such correlation can provide evidence from which a causal relationship is hypothesised, but it does not by itself demonstrate causation. A correlation may instead result from a common cause, reverse causation, interacting causal pathways, or unidentified conditions and constraints.

Stronger causal knowledge becomes possible when the causal mechanism connecting the phenomena can be identified. A causal mechanism comprises the causal organisation of processes, transfers, conditions and constraints through which causal influence propagates. Investigation can then test whether the proposed processes and transfers occur and whether their timing, organisation and effects are consistent with the proposed causal relationship.

This can be understood as causal decompression. An initially compressed relationship:

A → B

is progressively expanded to reveal the intervening causal organisation:

A → processes → transfers → conditions and constraints → processes → B

Complete decompression is neither always possible nor always necessary. The appropriate degree of detail depends upon the purpose of the investigation and the evidence available.

Hypotheses, explanations and theories are all epistemic representations of causal reality, but they perform different roles. A hypothesis provisionally represents a possible causal organisation and is open to testing. An explanation represents causal organisation considered sufficiently supported to account for a phenomenon. A theory represents causal organisation believed to recur across a class of phenomena and may therefore support explanations and predictions across multiple instances.

These representations remain corrigible. Individual parts of a proposed causal network may be supported while others fail, allowing the representation to be progressively revised rather than requiring it always to be accepted or rejected as an indivisible whole.

The explanatory power of a theory depends partly upon the recurrence of the causal organisation it represents. Where substantially the same causal organisation occurs across many instances or classes of phenomena, a relatively compact epistemic representation may explain a wide range of observations.

Plain English Explanation

Imagine that you notice that the town in our continuing example tends to flood after periods of heavy rainfall.

You have recognised a recurring relationship.

If records show that heavier rainfall is generally associated with more frequent flooding, you may also establish a correlation.

But neither observation, by itself, tells you exactly why the town floods.

Perhaps rainfall increases river flow until the river overtops its banks. Perhaps the drainage system becomes overwhelmed. Perhaps saturated ground greatly increases surface runoff. Perhaps several of these pathways operate together.

To establish causality more confidently, we therefore try to discover what physically connects the apparent cause with the effect.

We decompress:

Heavy rainfall → flooding

into something more like:

rainfall → ground and drainage processes → runoff → river and drainage flows → rising water levels → overtopping or drainage exceedance → floodwater movement → flooding

We can then investigate individual parts of this proposed causal mechanism.

Does runoff actually increase as predicted? Does it reach the river? Do river levels rise at the expected time? Is the drainage system exceeding its capacity? Where does the floodwater enter the town?

The causal explanation becomes stronger when the predicted parts of the mechanism can be observed or independently tested.

This also shows why correlation is useful even though correlation does not establish causation. Correlation tells us that there may be something worth explaining. Causal investigation asks what organisation of processes and transfers could produce the observed relationship.

A hypothesis might be:

"The town floods because heavy rainfall overwhelms the drainage system."

That is a provisional representation of possible causal reality. We can try to break it. If the drains remain well below capacity during a flood, an important part of the hypothesis has failed.

An explanation might emerge after investigation:

"Flooding occurred because saturated ground produced unusually high runoff while high river levels simultaneously restricted drainage discharge."

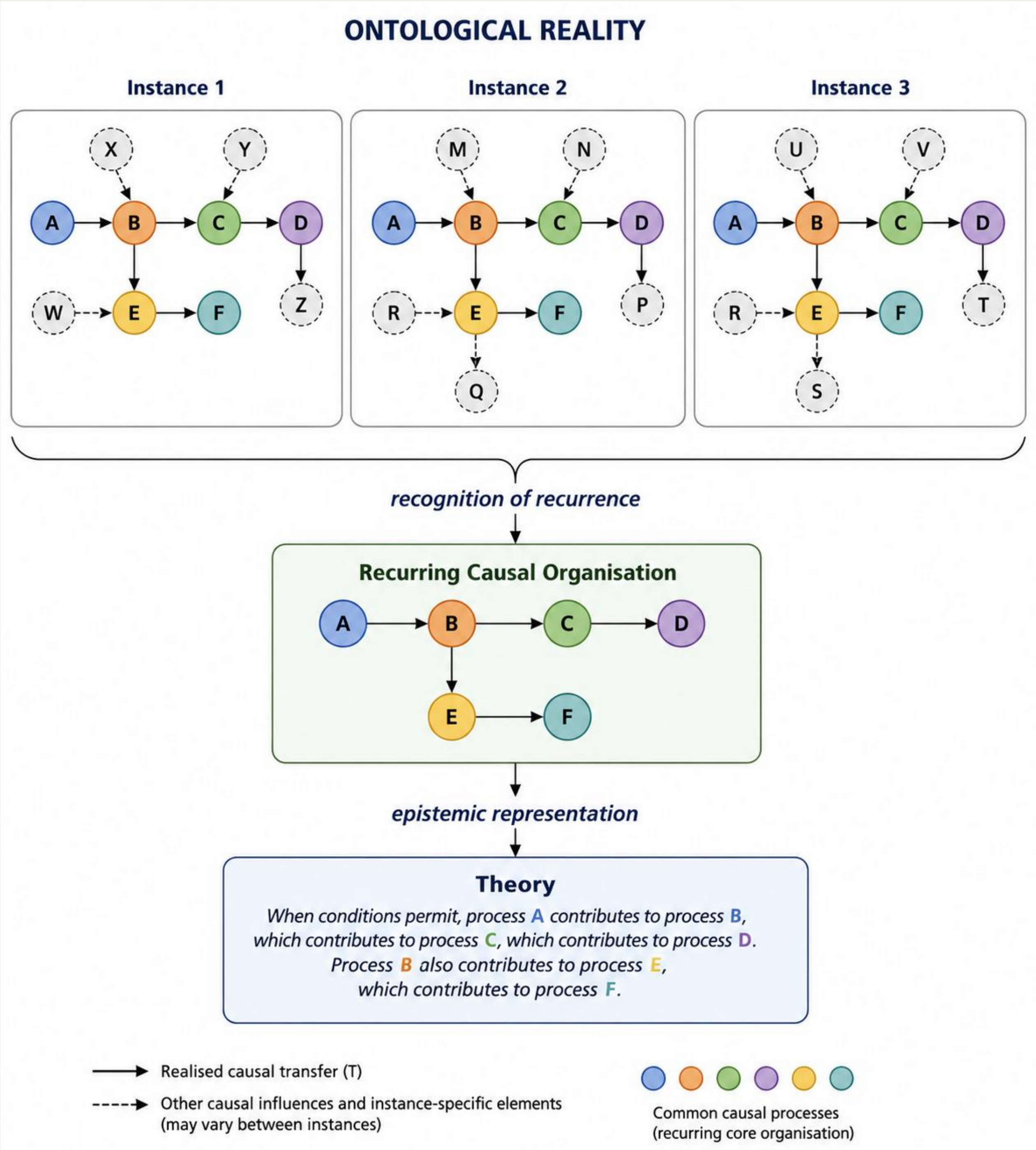
This represents a causal organisation for which we now have sufficient evidence to use it in explaining the event.

A theory goes further. It represents causal organisation expected to recur across a class of phenomena. If the same underlying relationships between rainfall, saturation, runoff, drainage capacity and receiving-water level recur in many locations, the resulting theory can help explain and predict flooding beyond the original town.

There is therefore a progression:

Causal reality → observation → recognised recurrence → causal hypothesis → investigation of mechanism → supported causal explanation → recognition of recurring causal organisation → theory

This should not be interpreted as an inflexible sequence. Scientific investigation frequently moves backwards and forwards between these activities. The important point is that our knowledge of causality consists of representations that are progressively tested against causal reality.



From Causal Reality to Theory

Recurring causal organisation may exist across different instances of causal reality. Recognition and abstraction of that recurrence allow an epistemic representation to be constructed as a theory. The theory represents causal reality but is not identical to it.

Examples

The relationship between smoking and lung cancer provides an important historical example. Epidemiological observations established a strong association before every biological mechanism involved was understood. Subsequent investigation of carcinogens, cellular damage and disease processes progressively strengthened the causal explanation. This illustrates how statistical recurrence and mechanistic investigation can provide complementary forms of evidence.

In engineering, repeated failure of a component under particular operating conditions may initially reveal a correlation. Examination may subsequently identify cyclic loading, crack initiation and propagation, eventually producing a causal explanation of fatigue failure. Understanding the mechanism then permits predictions and interventions that would be impossible from the observed correlation alone.

The relationship between rainfall and flooding follows the same general pattern. Statistical analysis may demonstrate that flooding becomes more likely under particular rainfall conditions. Hydrological investigation can then identify the physical processes and transfers responsible for that relationship and the circumstances under which it does or does not occur.

These examples also illustrate why causal explanations need not contain every possible detail. An engineer explaining fatigue failure does not normally need to represent every molecular interaction within the material. A useful explanation contains sufficient causal decompression for its intended purpose.

Provenance and Links

The distinction between observed regularity and causal necessity is strongly associated with David Hume, whose analysis of causation raised the enduring problem of what can legitimately be inferred from repeated association. Modern causal inference continues to address this problem through methods intended to distinguish causal relationships from statistical correlations.

Karl Popper emphasised the importance of exposing scientific hypotheses to attempts at falsification rather than seeking only confirming observations. This provides an important antecedent for treating hypotheses as representations that should be actively tested for points of failure.

Roy Bhaskar's Critical Realism provides a particularly important antecedent for the ontological position adopted in these modules. Bhaskar distinguished real causal mechanisms from the events we observe and from our knowledge of them, allowing causal mechanisms to exist and operate even when their effects are not consistently manifested because other causal mechanisms and conditions intervene.

Contemporary mechanistic philosophy of science, including the work of Machamer, Darden and Craver, similarly emphasises explanation through the identification of organised mechanisms rather than through regular association alone. Judea Pearl's work on causal inference provides a complementary formal tradition concerned with distinguishing causal relationships from statistical associations.

The particular synthesis developed in these course modules treats hypotheses, explanations and theories as epistemic representations of causal networks at different stages and levels of generality, while treating causal mechanisms as features of ontological reality. The concept of causal decompression describes the progressive expansion of compressed **A → B** representations to expose the processes, transfers, conditions and constraints through which the represented causal relationship is physically instantiated.

Practical Exercise

Return for the final time to the town experiencing local flooding after heavy rainfall.

Across the preceding exercises you have progressively transformed the original sequence:

Heavy rainfall → surface runoff → increased river flow → rising water level → flooding → property damage

into a much richer representation containing physical transfers, necessary and enabling causes, branching and converging pathways, causal structures, persistent organisation, system boundaries and possible leverage points.

Now imagine that you are beginning the investigation without knowing whether your representation is correct.

Start with the observed relationship:

Heavy rainfall is frequently followed by flooding.

Treat this initially as an observed recurrence or correlation. Identify at least two possible explanations for the relationship. Your alternatives should represent genuinely different causal pathways rather than different wordings of the same explanation.

Choose one of these as a causal hypothesis. Draw or describe the causal mechanism that would have to exist if your hypothesis were correct. Identify the principal processes, transfers, conditions and constraints involved.

Now try to break your hypothesis. Identify observations or measurements that would contradict important parts of the proposed causal network. Consider what evidence would be required to distinguish your hypothesis from the alternative explanation.

Suppose that some parts of your hypothesis are supported while another part fails. Rather than simply accepting or rejecting the whole hypothesis, identify which part of the represented causal network should be retained and which part requires revision.

Now assume that subsequent investigation provides substantial support for your revised mechanism. Rewrite the hypothesis as a causal explanation of the particular flood event.

Next imagine that similar investigations are undertaken in many towns. Some of the details differ, but recurring causal organisation is recognised involving rainfall, ground saturation, runoff, drainage capacity, river levels and flooding. Explain how abstraction from these recurring causal organisations could contribute to a more general theory of flooding.

Finally, return to the leverage point you selected in the previous module. Ask whether your proposed intervention still appears appropriate after treating your causal understanding as a testable epistemic representation rather than established reality. Identify what evidence you would want before implementing the intervention and what observations you would make afterwards to determine whether your causal expectations were correct.

Conclude the exercise by briefly explaining the distinction between:

- the flood as causal reality;
- your causal network as a representation of that reality;
- a hypothesis about how the flood occurred;
- an explanation supported by investigation; and
- a theory representing causal organisation recurring across many floods.

You have now followed the flooding example from a simple statement of cause and effect through progressively deeper analysis of its physical causality, causal network, organisation and possible leverage points, and finally to the construction and testing of causal knowledge.