9
The Theory of Causal Significance

9.1 Introduction

In part I, I argued for several problems that face the Liberal Naturalist's program for explaining consciousness. These were:

1. A puzzle, called *the boundary problem for experiencing subjects*, about why conscious experience exists at the middle level of the natural world even though it seems coherent that things could have been otherwise.
2. The possibility of panexperientialism, a more benign form of panpsychism. It even seems *likely* to be the outcome of Liberal Naturalism.
3. The unity of consciousness as a property of a seemingly disunified brain.
4. The seeming existence of a subjective instant.
5. Problems associated with the causal relevance of any extraphysical aspects of reality.
6. Sellar's grain problem about the structural homogeneity of phenomenal properties.

While exploring most of these problems, I suggested ways to view them as providing reasons to look more deeply into causation. Discussion of the boundary problem ended with questions about how interactions might create layers of inherently individuated subregions of the world. The riddles surrounding the unity of consciousness and the grain problem could point to questions about causal-functional roles, and functional role questions are ultimately questions about causation and causal interaction. The paradox of the subjective instant leads to questions about time, and potential ties between the direction of causation and the direction of time are enticing targets for exploration. Most obviously, the problems associated with the causal relevance of consciousness cry out for an in-depth treatment of causation.

The argument that raises problems for the causal relevance of consciousness contains a promisingly questionable inference: It moves from the scientific adequacy of physical explanations to the conclusion that physical explanations tell everything fundamental there is to know about causation. To my knowledge, this inference has never been formally challenged. In this chapter I challenge that inference. To do so, I need to present a solid idea of what causation is and what a full explanation of causation should look like.

The theoretical framework I develop is called the *Theory of Natural Individuals*. The first piece of the framework, developed in the next three chapters, is the *Theory of Causal Significance*. This chapter is an introduction to the Theory of Causal Significance that is intended to motivate the general approach the theory represents and to introduce and explain the basic concepts. This chapter:

Defines the problem of causation, explaining why a theory is needed and important.

- Explains why physics is not a theory of causation.
- Gives a taxonomy of traditional approaches to causation and explains why the Theory of Causal Significance must fall outside of the traditional taxonomy.
- Abstracts a very general essence of causation that the Theory of Causal Significance can represent and shows how to modify the traditional taxonomy to create a place for the Theory of Causal Significance.
- Emphasizes that causal significance is not necessarily the production relation of cause and effect.
- Introduces the ideas of effective and receptive properties, arguing that they are conceptually and empirically distinct aspects of causation. Together, these properties are said to provide the *nomic content* of an individual.
- Defends a proposal to treat receptivity as a connective property.
- Analyzes the causal nexus, defining key terms, giving examples, and laying down the fundamental principles of a theory of the causal nexus.
- Explains what a natural individual is and discusses how and why natural individuals might emerge at many levels of nature.

9.2 The Problem of Causation

What is the problem of causation? Imagine two great, blank canvases that you cover with color one drop at a time. Imagine also that the two canvases are very different kinds of surfaces with which to work. You call the first canvas the Humean canvas, and it will accept any drop of paint anywhere on its surface in any color that you let fall. If you let a drop of red paint fall onto the Humean canvas, it will stick where it lands. The same will happen if you then drop a speck of yellow paint somewhere else on the canvas. You can fill the whole canvas this way, dropping colorful spot after colorful spot on the Humean canvas until its surface is covered with colors lying beside one another in any combination whatsoever. The canvas cares not a whit what the end product looks like, ugly or beautiful or anything in between.

You call the second canvas the Canvas of Causation, and it is more of a marvel. If your first drop of paint is a bit of green, and then you try to place a dollop of red next to it, the red paint will bounce off. The canvas will not accept it. But it will accept yellow. And the more paint you put on the canvas, the more subtle and picky it becomes. Each bit of color that sticks to its surface seems to place a constraint on what colors may appear anywhere else on the canvas. In fact, although the canvas will allow you to paint it many different ways, it will accept only combinations of color that make for a beautifully covered canvas, so that somehow the canvas enforces aesthetic laws. Every color and every drop matters, jointly enforcing or excluding the colors that will finally appear on the canvas.

Although the Humean canvas is ordinary, the Canvas of Causation seems like magic. The two canvases are two possible ways the world could be. The drops of paint represent events that occur in the world, and the laissez-faire chaos of the Humean canvas represents a world in which anything can happen anywhere, regardless of what else might have occurred. The magical pickiness of the Canvas of Causation and its aesthetic laws represent a world in which laws of nature suggest a connection between each event so that every one must somehow respect the nature of every other. It is a world in which nature includes and excludes membership based on what else has made it into the club.

The problem of causation is that we do not live in a Humean world, even though the Humean canvas seems so much simpler to make than a Canvas of Causation. Making a Canvas of Causation requires some extra ingredient over and above simply having a world in which things can happen, and it is not clear what this extra ingredient is or what it means for our understanding of the world in general. Given that our world is like the Canvas of Causation, it seems that there is some magic in it somehow that connects things to one another in a deep way. The problem of causation is to understand what that really means for the nature of things.

9.3 Physics Is Not a Theory of Causation

On the path to understanding causation, the place to start is with physics, the aspect of causation that we understand best. A realist but Humean interpretation of physics is easily available to us, and this easy availability of a Humean interpretation exposes the danger that physics might not be telling us the whole story about causation. Physics might be describing only an aspect of causation, and, by realizing its potential shortcomings, we will be in a better position to find what is missing.

A description of coevolving fields is the centerpiece of quantum mechanics, our most basic physical theory. These fields expand and periodically contract, for reasons still unknown, to something like classical, localized particles, and then they begin to spread in spacetime again. The dynamical laws tell us how any given field will evolve given its state at some time in the past, and they tell us how the evolutions of different fields become correlated. The current theory does have a gap in its dynamics because it must appeal to the ill-defined concept of measurement to specify when the contractions of the fields occur. This gap in the theory should not matter to the discussion that follows.

The evolution of a field is represented by a dynamical equation called the Schroedinger equation. Schroedinger equations plot states of the system, represented in a matrix, against points in time. Given an initial state, the mathematical rules they express describe a temporal trajectory through the field's space of possible states. The relevant feature of such dynamical equations is that their successful use requires us only to assume regularity in the succession of states. They merely associate, or correlate, field states with points in time. Association is a weak metaphysical relation because associations could exist for just about any reason or for no reason at all.

Specifically, the mathematical machinery is neutral with regard to how these associations arise. Nowhere does it mention or need the idea of causal production or dependency between states of the system at different times. The only explicit associations in the *function* are between states of the system and points in time. It is the explicit and implicit associations represented in the function that contain the causal content of the theory. There is no need for the hypothesis that one state of the system might causally depend on or be connected to another by more than their places in the overall extrinsic pattern. If we choose to interpret the mathematics causally anyway, this interpretation is projecting something into the theory not explicitly represented nor logically required by its equations.

The second component of physical theories describes how these fields "interact." I put "interact" in scare quotes because this part of the theory is also compatible with a Humean view of nature. The laws describing interactions express correlations between the evolutions of different fields. Like association, correlation is a weak relation and compatible with the absence of any real connection between the fields. It is true that physical forces are supposed to mediate these interactions, but virtual particles carry these forces. We can always interpret virtual particles as further field elements entering the correlation story.

In the end, a realist interpretation of the equations governing interaction requires only that we recognize the highly regular correlation between the evolutions of different fields. Like talk of connections of causal dependency, connections of interaction and exchange of "information" (in any active sense of "information") is projected into the theory. We do this because we would find the world the theory tells us about impossible to believe in without such connections and not because the theoretical apparatus logically requires us to think that way. Particularly, the theory does not represent causal connections. If we choose to interpret physical theory in a non-Humean way, we must take it as assuming causal connections implicitly while explicitly describing some aspect of their outcomes. In this chapter and the next, I try to make the reasons for this clearer. In chapter 11 I give a formal argument for the conclusion.

One can think of this theoretical apparatus as a kind of probabilistic road map. It helps us navigate the four-dimensional surface of spacetime using landmarks to help fix our expectations. To be a successful map, it needs to make only modest demands on nature, not requiring anything more of nature beyond the regularity of relations between the landmarks.

The metaphor of a map tells us how we can be both realists and Humeans about physical theory. Corresponding to every physical property in the theory, we postulate something in nature. We can think of “mass,” “charge,” “spin,” and so forth as each denoting a property present in the appropriate magnitudes at the appropriate places in spacetime. These properties are distinct and capable of the specified quantitative variations. They act as the landmarks on our maps. That makes us realists about the science because we are taking it to refer to objective properties belonging to things outside of us and describing them accurately.

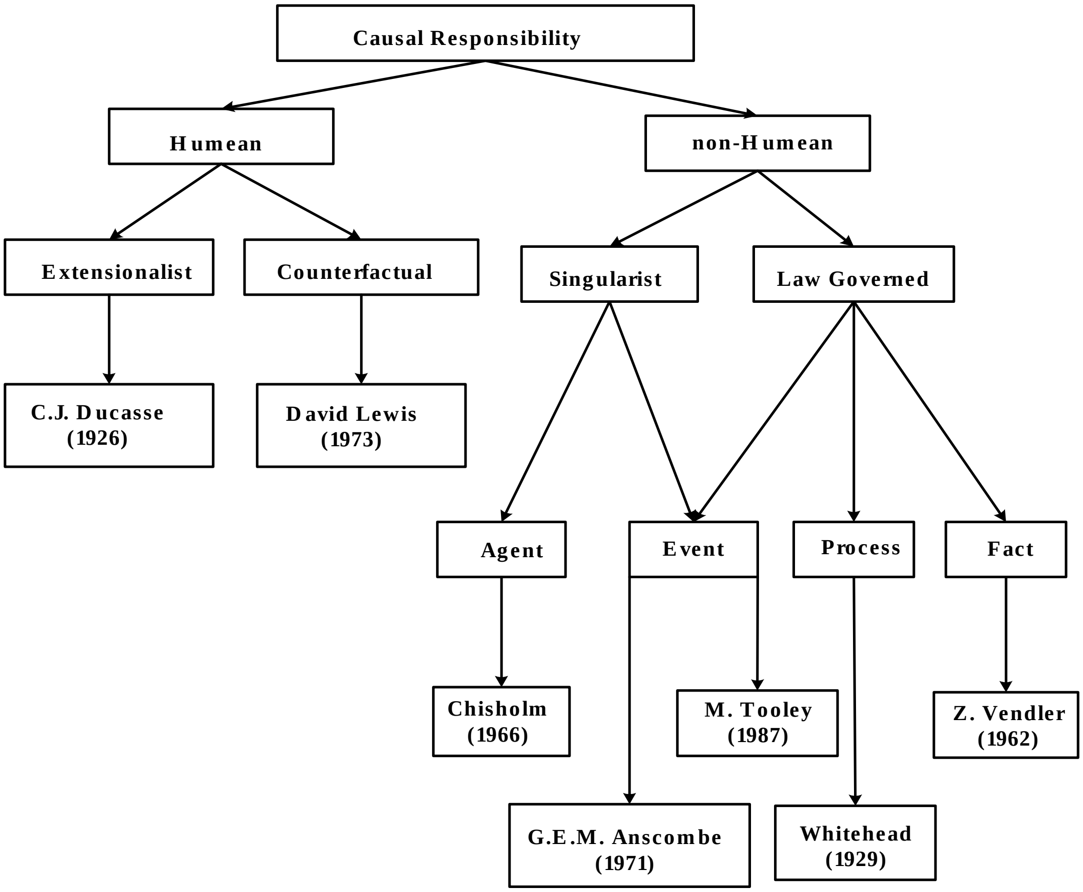
The theory can be true, and true in a realist sense, even if we do not postulate further things such as connections between the landmarks. The landmarks simply have to vary in the regular ways that the theory describes so that spacetime has the appropriate layout. We do not need to suppose that some landmarks produce others or constrain the production of others. Therefore we will not postulate these things. That makes us Humeans.

Just because we can easily see how to be Humeans about physics does not mean that we *have* to be Humeans about it. Humean views have deep problems, as I argued in the last chapter, and the most common and compelling interpretations of physics are causal. I am suggesting that the ease and directness with which we can construct a Humean interpretation should serve as a warning that we cannot make the move to a fully causal interpretation for free. To make sense of unnoticed background assumptions, we may require ontology that physical theory does not explicitly represent. Perhaps we will have to take physical theories to be explicitly representing some *aspect* (or aspects) of causation, while allowing others to live *implicitly* in the background. The business of the Theory of Natural Individuals is to find and more explicitly characterize these implicit categorical grounds of causation.

Admittedly, I have not said anything about the hypothesized quantum collapse of the wave function or alternatives to standard quantum mechanics, such as hidden variable theories. None of these things make a difference to the general point, which rests on an observation about what our physical theories actually require from us to deliver their results. To do their empirical job of predicting or explaining what we observe at some region in spacetime, they require us only to possess certain minimal information about the values of physical properties involved in some other events that have occurred elsewhere in spacetime.

9.4 Causal Responsibility

Many philosophers of causation tacitly assume that their first choice is between a Humean conventionalist approach and some form of nonconventionalist approach. The decision tree that seems to be active among theorists is depicted in figure 9.1. The root node of the tree, labeled *causal responsibility*, represents the assumed ultimate object of explanation for a theory of causation. Facts about causal



responsibility are facts about what makes a productive cause and how these causes relate to their effects.

Theories of causal responsibility are theories of general conditions under which a specified something—event, agent, fact, or process—can be credited with being the cause, partial or total, of some specified event(s), its effect(s). The branches of the tree are choice points along the way to developing this theory of causal responsibility. The approach I develop here differs from the standard approaches at this very first choice point by rejecting causal responsibility as the fundamental explanandum for a theory of causation.

I steer away from the tradition because it is not fully objective. Our ordinary notion of causal responsibility has strong intentional and interest-relative components. The intentional aspects betray themselves when negative facts show up as causes in both ordinary and scientific explanation. For example, when an animal starves to death, we judge that the cause of death, which is a *loss* of life, was the *lack* of food. Along the same lines, we often say that a person's disappointment in himself or another was caused by some *failure*, where failures are understood as things that were *not* achieved.

It is not so easy to eliminate the negatives from such examples and, more important, it is not worthwhile. For example, perhaps we may define death in positive terms as the presence of monotonically increasing entropy in the organism. Assume that a wicked pet owner starves his or her pet to death by locking it in a closet. What is the cause of the monotonically increasing entropy that eventually takes hold in the pet? There is certainly a complicated story concerning positive facts to be told, but this story is at a level below which we assign causal responsibility and misses the key fact: The pet was prevented from eating. A court would say the death was caused by neglect. Still, a coroner might cite liver failure as cause of death. A systems-oriented biologist might cite failure of systemic homeostasis. It depends on one's prior interests and point of view. Finally, for some negative facts, such as the feelings of disappointment caused by someone not showing up for a date, there truly seems to be no sufficient set of positive facts to substitute for purported negative causes. The problem raised by such scenarios is that facts about absence require appealing to intentional objects such as universal "That's all" facts. These are universally quantified facts that are logically equivalent to negative existential facts.

Figure 9.1 A taxonomy for traditional theories of causation. The leaf nodes represent chief proponents from the twentieth century for the corresponding view.

Furthermore, if one were to produce a complicated set of purely positive facts, assigning causal responsibility from this large set of positive facts yields to the problem of deciding what counts as figure and what counts as ground in such judgments. The interest-relative aspect of causal responsibility shows itself in judgments that essentially involve a kind of figure/ground relation. Imagine a typical morning when Trey goes to work. Before getting on the road, he puts the car key in its slot, turns it, and starts the engine. Although our common idea of causal responsibility will credit Trey's turning of the key as being the cause of the engine's starting, notice that the counterfactuals involved underdetermine this kind of judgment. Although it is true that the starting of the car would not have occurred had the key not been turned, this same counterfactual holds of many other facts: Had his morning alarm not gone off, Trey would still be sleeping and thus the starting of the car would not have occurred; had the spark plugs not fired, the car would not have started; had the earth stopped turning, the car would not have started; and so forth. The counterfactual seems to be an important condition, but the truth of such counterfactuals is not sufficient to yield facts about causal responsibility. Giving a sufficient account seems to bring in interest-relative factors relying on idiosyncrasies in human judgment (such as how we might judge the similarity relations between two possible worlds).

One might try to remove the figure/ground problem by expanding the scope of causal responsibility to include all facts necessary to produce the effect. However, we have learned now that previous states of the world do not necessitate subsequent states. Therefore, assignment of responsibility must come on some other grounds, such as making the subsequent states of the world more probable. Assume that time is continuous, and let C be a state of the world proposed as being causally responsible for an effect E occurring later in time. For any C and E, there will be a state of the world C^* between C and E such that C^* makes E at least as probable as C does and which is closer in time. There is therefore no objective reason—no reason which matters to nature—to make C rather than C^* the state which is causally responsible for E. The issue is decided based on human interests. Perhaps time is not continuous, so such problems are only apparent, but a theory of the deep structure of causation should not be hostage to such matters.

For such reasons as these, I believe that facts about causal responsibility are unlikely to be similar to facts about rocks, things that we simply trip over while investigating the world's objective causal structure. These aspects of our ordinary concept of causation create a striking portrait of a convenient explanatory construct rather than an objective natural relation, and judgments of cause and effect seem like ways of characterizing certain striking patterns. I believe these intentional and interest-relative aspects of causal responsibility are what can make the conventionalist views about causation seem plausible.

The intentional and interest-relative aspects of causation have been especially emphasized by R.C. Collingwood (1940). More recently, D.H. Mellor (1995) has emphasized the tight relation between the notion of cause and being a means to an end. To move past conventionalism, it will be necessary to dig through to an objective core. Because a metaphysically robust kind of causation must exist (per the arguments in the last chapter), facts about causal responsibility must arise from a mixed notion, one that contains an objective core on which the more intentional and interest-relative facts rest. We are stalking an explanation of this objective core, not causal responsibility itself.

9.5 Causal Significance

A robust metaphysical theory of causation will provide a viable realist alternative to conventionalism. The preeminent theoretical virtue guiding construction of the theory of causal significance will be *simplicity*. I begin with the question, *What is the least set of features a world must possess to make conventionalism false in that world*? Notice that the concept of causal responsibility comes loaded with *default assumptions* about the character of causal relations. Among these assumptions are the ideas that causal relations are asymmetric, that they exist only forward in time, that they are only local in space, perhaps that they involve events, and that it is a two-place relation.

We can treat these assumptions as default values of parameters on a more basic concept. These parameters are: its arity (how many elements are involved in the causal connection?); categorical constraints on the relata (do effects and causes need to be events?); symmetry (is the causal connection symmetric or asymmetric?); directionality (if asymmetric, in which direction does the connection go?); and locality (does the connection respect spatiotemporal proximity?). The next step in the analysis investigates whether these parameters need to have any specific values to make conventionalism false in a given world. Taking them one at a time:

The arity of the relation The arity of a relation refers to the number of things related. The ordinary language idea of causation seems to be of a two-place relation, but conventionalism could clearly be false even if causation were a relation between more than two things. In fact, Evan Fales (1990) has proposed that causation in our world is really a six-place relation between two points in space, two points in time, and two properties.

The categorical constraints on the relata Hume wrote of causation as a relation between events. Many philosophers, such as Davidson (1967), apparently following Hume, often model it metaphysically as a relation between events. However, Vendler (1962) collected detailed linguistic evidence that in ordinary language it is often a relation between a fact and an event. Also, on the metaphysical level, libertarian philosophers have introduced the notion of agent causation, in which agents are causes. Finally, the tradition of process philosophy, as well as Wesley Salmon's (1984) empiricist view on causation, draft processes as essential elements of causation. One can argue about which proposal best captures causation in our world, but it seems clear that conventionalism could be false regardless of the kind of proposal accepted.

Symmetry Although our ordinary concept of causation distinguishes between causes and effects, we can imagine a world with symmetric constraints, such as constraints on the simultaneous state determinations of multiple individuals. For example, there could be a world in which a group of tossed coins are constrained to come up in only certain combinations of heads and tails. In these worlds, we imagine the laws of nature ruling out the occurrence of some *combinations* of events, even though each coin, tossed individually, could come up heads or tails. Such a world would not be a conventionalist world because there would be a metaphysical constraint between distinct events. Our world even seems to be such a world, as the quantum constraints on the states of entangled particles rule out some joint instantiations of otherwise possible states. Thus conventionalism could be false even if there were no distinction between cause and effect.

Directionality Questions about directionality arise only in worlds with asymmetric causal constraints. If asymmetry is not essential to causation, then directionality is obviously not essential to it, either.

Locality Quantum physics provides reasons for believing that constraints hold between things nonlocally even in *our* world. An objective basis for the existence of such constraints would be enough to falsify conventionalism. In general, any world in which causal asymmetry is broken in the manner I described earlier could easily violate locality without falling into conventionalism. This idea was first pointed out as a consequence of quantum mechanics in a famous thought experiment proposed by Einstein, Podolsky, and Rosen, later theoretically confirmed by John Bell, empirically confirmed by Alain Aspect, and subsequently reconfirmed by others.

Judging by these considerations, it does not seem as if the parameters on causation need to have specific values to ensure the falsity of conventionalism. Explicit reflections show that our ordinary concept of causation is only one among many possible specifications of a more fundamental and general concept. This more fundamental concept is simply one of real constraint between distinct entities. If a realist view of causation is correct, then the occurrence of an event (for instance) has *significance beyond itself*, a significance that ripples widely through an ontologically interconnected causal mesh, forcing the rest of the world to be, in some sense, compatible with its occurrence. A realist theory of causation will give an account of what causal significance, in this sense, is.

Definition 9.1: The *causal significance* of a thing is the constraint its existence adds to the space of possible ways the world could be. A successful *theory of causal significance* should lay bare an objective base of facts on which less objective facts about causal responsibility might rest.

Causal significance shows causation to be an operator on a space of possibility. The recognition that a theory of causation can be a theory of causal significance yields a revised decision tree, as depicted in Figure 9.2. Causal significance represents the deep structure of causation, and finding a clearer understanding of the deep structure of causation is how a Liberal Naturalist will probe the deep structure of the natural world.

What do I mean by *the deep structure of causation*? By focusing on causal significance, I am suggesting that the causal realist should treat our ordinary idea of causal responsibility as something akin to the surface structure of a grammar. According to one school of thought, the grammar of a specific language is an idiosyncratic development of a more general and universal structure, called the deep structure of language, which is common to it and all other possible human grammars. By analogy, I am proposing that the way we have come to think about causation in our world represents the surface structure of the deeper grammar of causal constraint common to this and all other possible causal worlds. The *deep structure of causation* is the concept of real constraint, conditioned by a variety of parameters whose specific settings represent hypotheses about the structural features that direct the flow of constraint.

9.6 Causal Significance Replaces Causal Production

A theory of causal significance will have a radically different form than we would expect from a theory of causal responsibility. Theories of causal responsibi

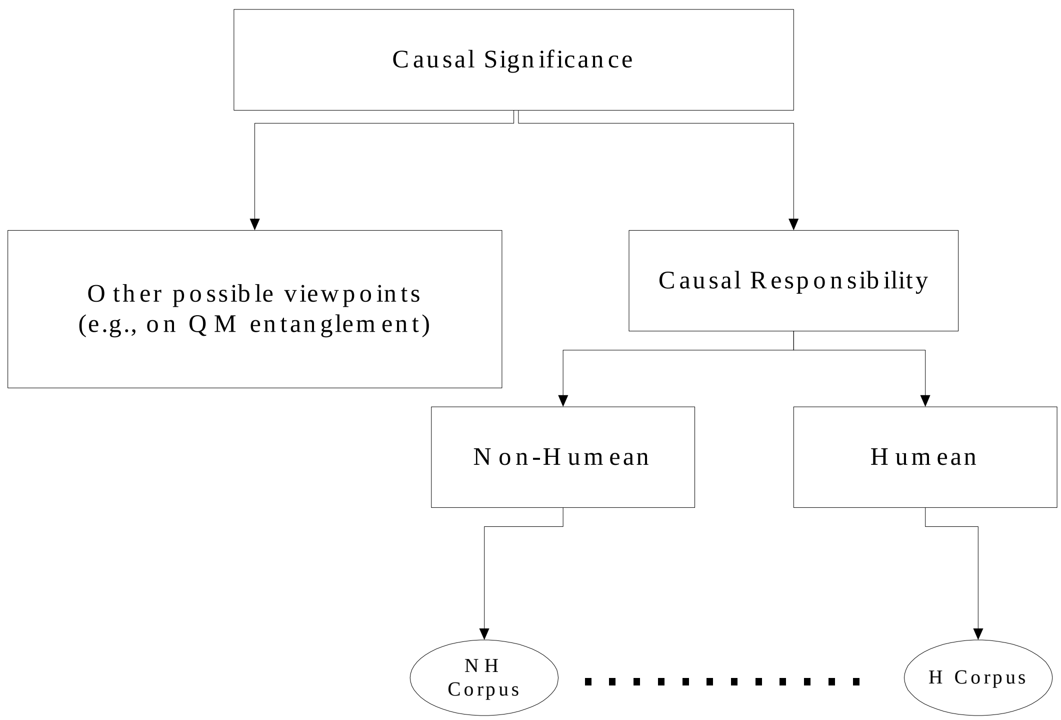


Figure 9. 2 Causal responsibility incorporates intentional facts and can be viewed as a refinement of causal significance.

lity invite us not to focus on constraint but on causal powers capable of bringing other things about, on causes producing effects. Therefore, theorists of causal responsibility tend to produce theories of causal production. In a deep sense, theories of causal responsibility start from perplexity that changes occur (why did something happen?), and their driving metaphysical question is the ancient question: *Why is there something rather than nothing?*

In contrast, the core concept behind causal significance is not production. Because production requires one thing to in some sense come "out of" another, production is asymmetric, directed, and naturally limited to local connection. Recall from the previous section that these features of our concept of causation are specific developments of a more general concept of causal significance. If the deep structure of the natural world is a structure of natural constraint, then the logic of constraint leads to a focus on selective inclusion and exclusion rather than production. Conceptualizing the world as the ultimate clique directs questioning toward the discovery of the secret character by which the world denies existence to so many things that could have been.

The humble truth is that, for all we know, existence might be something toward which all things tend. If so, what requires metaphysical explanation might be why some things *aren't* rather than why some things *are*. Perhaps the fact that new things can come into being is part of the noncontingent nature of the world, and perplexity should start at observation of how restrained these facts are in reality. Most possibilities do not occur.

Picture the world as a jewel set in a heaven of transparent possibilities, each flowing along its surface, peering as if at sparkles on ice seen through a window, fingers gently probing for an opening through which it can pour itself. The thought that there could have been nothing becomes strange, and it can seem quite puzzling that there is not much more. Like Robert F. Kennedy, we are not seeing things that are and asking, "Why?" but are dreaming of things that are not and asking, "Why not?"

In a deep sense, the search for a theory of causal significance suggests that the grand metaphysical question all along should have been: *Why is there something rather than everything?* Why doesn't every arbitrary combination of properties occur? This theory of causal significance, the theory underlying the magic of the Canvas of Causation, will be a theory of symmetric and asymmetric *state-constraint* between individuals. It is a theory designed to understand how constraints propagate, so it explains how the actual world comes to be just a sliver of what could have been.

One billiard ball hitting another is a paradigm case of one event causally producing another, and so "billiard ball causation" is not necessarily the best paradigm case of causal significance. A better paradigm case might be two entangled quantum particles. Two entangled particles are similar to two coins that must always be flipped together and that share a special constraint. Although each coin could land either heads up or tails up if it could be flipped separately, making for four possible joint states between them, because the two coins are entangled they share a *constrained joint state* in which each can land heads or tails only if the other one also does. So they could both be heads, or both be tails, but they could not come up one tails and the other heads. In this sense, the state of each has *causal significance* for the other, and their mutual causal significance excludes two possibilities. "Causal significance" names the presence of constraint between them, while not necessarily explaining the state of one by assigning responsibility or temporal precedence to the other.

Causal significance is produced by the set of causally relevant properties an individual possesses. Collectively, these properties constitute an individual's *nomic content*.[i] I analyze nomic content into two fundamentally different but interdependent kinds of properties: the *effective properties* that are responsible for an individual's capacity to constrain the states of other individuals and the *receptive properties* that form a network of connectivity, allowing individuals to place the constraints potential in their effective states.

9.7 Effective Properties

Reflect on how we create physical theories. We are creatures fully embedded within the natural world, and physical theories are our attempts to understand something about the causal order of that world. When we self-consciously consider the position we occupy, the character of the information we gather and hold physical theories accountable for becomes more apparent.

Nature places human beings within an effective loop. We must understand how the world may change us, and we, it. Fortunately, perception provides information to help with this challenge. Through perception we become systematically sensitive to environmental influence, treating some of its effects on us as providing information. Perception selectively processes effects that the environment may have on us, converting those it can into informational fuel that we burn and store in forming our interpretations.

Physicists have strongly tuned the methodology of physics to the effective nature of the world. The genius of the experimentalist is in solving the following challenge: Assuming that the entities we postulate are present, how can we isolate them and identify their states? The basic measuring devices they begin with are those of our biological endowment: eyes, ears, nose, tongue, and touch. The experimental physicist must find ways for perceptible and nonperceptible entities to make a distinctive difference to us via our biological endowment.

For nonperceptible entities, the experimental physicist first finds something else that the ultimate object of investigation can affect; then the experimental setup must magnify this effective difference through a chain. Near the end of this chain is something—perhaps a pointer, a colored flame, a visible vapor, or a computer display—that can affect our senses without the further aid of special instruments. At this last step, the effective natures of our instruments act on our biological endowment, completing the chain. In short, when we measure, we find effects of the hypothesized entities that we can magnify to a level of reality that we can perceive directly. The character of the entire process forces the effective dispositions of things into our theoretical fold because it is always a chain of effects, from hypothesized entities to us, whose explanation we require.

These properties are *effective* because their presence constrains the states that other individuals may also or subsequently have,[ii] and experimental science is possible because human beings can arrange and rearrange circumstances so that the total constraint structure changes the state of our biological endowment in systematic ways relative to the property being investigated. With enough information about this systematic variation, we are able to infer the character of the underlying constraints.

In short, the fundamental physics of our universe will be the science that *at least* discloses to us the effective dispositions of the fundamental individuals[iii] of our universe, assuming such individuals exist. However, none of this implies that physics will yield a complete account of the world’s causal structure. Doubts exist because effective properties require the existence of other kinds of properties.

The three questions that are the focus of this and the next three chapters are: (1) What other aspects of causation exist? (2) How do these different aspects interrelate? and (3) Are these other aspects physical? I argue that causation has two further aspects and that neither is plausibly physical.

9.8 Receptive Properties

This seems to be a *conceptual* truth: A property of an individual may be effective only if some individual is receptive to the property's presence. The two notions, effectiveness and receptivity, are logical complements of one another, so the world cannot realize one without the other. Thinkers in the history of philosophy have often recognized this duality, but usually only briefly and obliquely. For example, in Plato's *Sophist,* the character of the Stranger speaks for the materialists of antiquity, saying:

> I suggest that anything has real being that is so constituted as to possess any sort of power either to affect anything else or to be affected, in however small a degree, by the most insignificant agent, though it be only once. (247e, Hamilton and Cairns, 1961)

Receptivity is something like this *power to be affected* that Plato briefly points to, as does John Locke in chapter 21 of *An Essay Concerning Human Understanding*:

> Power thus considered is two-fold, viz. as able to make, or able to receive, any change. The one may be called active, and the other passive power. Whether matter be not wholly destitute of active power, as its author, God, is truly above all passive power; and whether the intermediate state of created spirits be not that alone which is capable of both active and passive power, may be worth consideration. (Locke, 1690)

This old distinction between active and passive power has fallen to the periphery of modern thinking. Likely, part of the reason is the previously discussed empiricist deflation of causation begun by Hume. Another part of the reason may be the unfortunately oxymoronic name, *passive power*. Despite the empiricist neglect, the idea remains an important part of process philosophy, where process philosophers recognize the logical need for something that does its work (e.g., Griffin 1997).

At times, the conceptual distinctness of receptivity and effectiveness has led us to postulate special kinds of individuals possessing only one of these aspects. For instance, the medieval/Aristotelian conception of God as a purely active force (mentioned by Locke), or unmoved mover, is an isolation of effective properties within a nonreceptive individual. On the other hand, dualist proposals about consciousness are sometimes epiphenomenal. They postulate that phenomenal consciousness is determined by the physical properties of the brain but is nevertheless causally inert. This is the postulation of an individual with properties that are receptive but not effective.

One can intuitively triangulate in on the distinction by considering each case and then identifying the complementary kind of property as what is *missing* in that case. What would an unmoved mover be *missing* so that it, alone among all beings, would be unresponsive? Equivalently, what is it that other beings have that it does not? Answer: It is missing a receptive aspect. What would an epiphenomenal consciousness be *missing* that would make it, alone among all beings, epiphenomenal? Equivalently, what is it that other beings have that it does not? Answer: It is missing an effective aspect.

Because of obvious problems in gaining knowledge about the presence of a purely receptive being, we would not expect any established science to have accepted the existence of one (modulo, controversially, consciousness itself). But has science ever found it intelligible to propose purely effective beings analogous to unmoved movers? Surprisingly, at least one example exists and, maybe, another. The clearest example of a purely effective entity is Newtonian space. Its Euclidean geometry constrained the movement of objects within it, although it was entirely unresponsive to its occupants. From the perspective we are now discussing, the causal difference between Newtonian space and Einsteinian space is twofold. First, the introduction of a different geometry represents a change in its effective nature. Second, Einstein introduced responsiveness to the distribution of mass within it. This second change is an entirely different kind of addition, ontologically, and the more revolutionary. Einstein added *receptivity* to space.

Although Einstein robbed Newtonian mechanics of its only unmoved mover, he may ironically have introduced another kind of his own: singularities. As entities with infinite density, singularities seem to have great effect on the rest of the universe. For instance, they create black holes. On the other hand, it is not clear that anything can, even in principle, affect them in return. Singularities may lack receptivity.

Collectively, these examples show the conceptual and empirical distinctness of effectiveness and receptivity. This distinctness marks an important point: They are not identical aspects of causation. These two aspects of the causal process do different jobs, and they need distinct accounts. A proper account will detail how each aspect helps to ground the very possibility of causal activity. Importantly, each aspect presupposes the possibility of the other's existence, so the conceptual relation between these two aspects of causation, the effective and receptive, has a circular structure. They are thus interdependent and equally fundamental aspects of the causal nexus.

I will revisit the case for receptivity in chapter 13, summarizing both these philosophical reasons for accepting its existence and further empirical reasons given in the next few chapters. For now, we know that (1) we should interpret physical theory in a causal realist way; (2) the ideal physics will include *all* the effective dispositions of our world's fundamental individuals, and (3) the effective and receptive aspects of causation are conceptually and empirically distinct.

Points (1)–(3) have already been established. For a moment, I assume something that I will argue for later, that (4) physics exhibits *only* the chain of regu larity between instantiations of the effective properties. If all of (1)– (4) are true, it follows that causation in our world has at least two equally fundamental aspects, and that one of them, receptivity, is left out of physical theory. Receptivity is an explanatory luxury for physical science, but it is nevertheless metaphysically relevant to the causal structure and evolution of the world.

If premise (4) is true, the overall ontological picture becomes very interesting. Receptive properties are necessarily related to the physical in that the physical properties are only effective properties, and something's being effective presupposes something's being receptive (and vice versa). In a world that realizes effectiveness, we have a necessary coinstantiation of logically distinct essences. Nevertheless, the logical connection between these aspects is not one of supervenience (because it is mutual), and the necessity connecting them is not merely nomic (because it is not logically contingent). It is a natural dualism of necessarily connected dualities, but not one that involves a merely nomic, external connection. We are on the cusp of a significant metaphysical proposal for the nature of causation that takes us beyond physicalism.[iv]

9.9 Receptivity as a Connection

If receptivity itself provided a connection between individuals, it would support a metaphysically far richer theory than a simple sponge metaphor in which receptivity is just another kind of monadic (i.e., one-place) property. Figure 9.3 visually contrasts the two alternative pictures. In this section I develop a connectivity view of receptivity.

I have several reasons for eschewing the monadic alternative and preferring to model receptivity as a connection. One reason is that, if one adopts the monadic view of receptivity depicted at the top of figure 9.3, the problem of "activating" an individual's receptivity relative to the effective states of other individuals remains. An individual cannot just be receptive *simpliciter*: It must be receptive *to* the effective state of some other individual(s). To complete the account, we would have to specify some conditions for selectively determining which individuals a given individual will be receptive to. This further condition, whatever it might be, is a complication to the model that does not arise if one begins by modeling receptivity as a connection.

Aside from the inelegance this extra step introduces, it also tends to limit the account in unnecessary ways. For instance, the tempting further condition is the classical assumption of spatial or temporal contiguity. This classical move rules out nonlocal causal connection by definition, which seems undesirable. It also brings spacetime into the picture in a fundamental role, precluding the otherwise attractive possibility of reducing it to more fundamental facts about causal connection.

A second reason for preferring the connection view is the very elegant modeling of levels of nature it allows, at least with respect to the emergence of higher level individuals incorporating lower level individuals. What the connection view

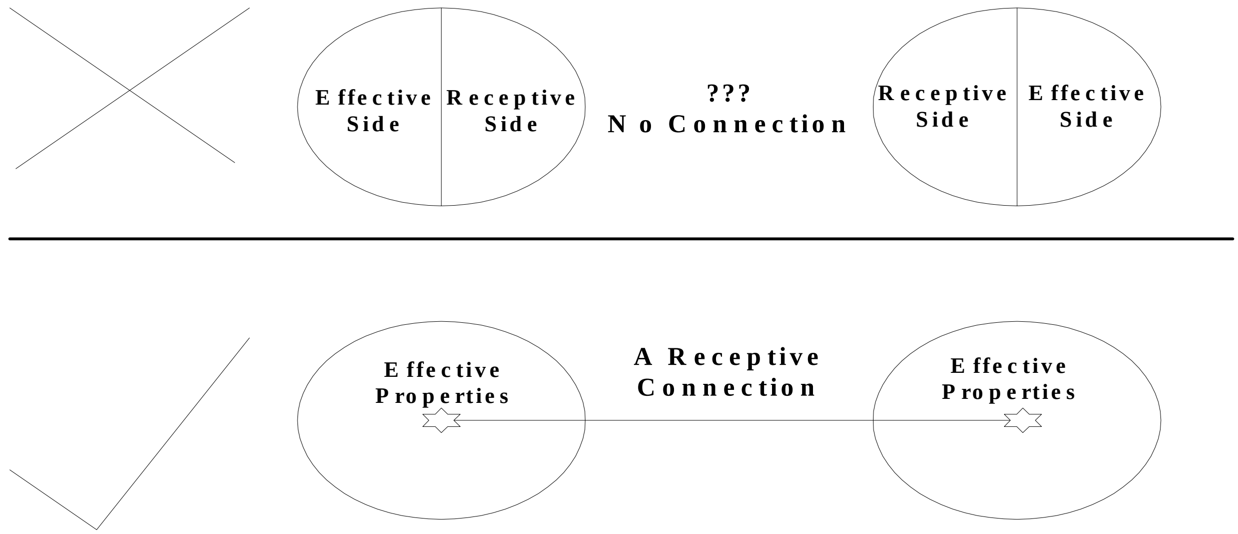


Figure 9.3 The Theory of Causal Significance will suppose that receptivity is a special kind of connective property different in some crucial ways from a traditionally conceived monadic property.

offers is an opportunity to specify the conditions of a substantial internal unity—a shared receptivity by multiple individuals—that may ground a notion of natural individual and natural individuation. Receptive connections, and thus natural individuals, could exist at any level of nature, and so there would be no special pride of place given to microphysical individuals. This feature dovetails well with modern science, as seen earlier in Michael Lockwood's observation that:

> In quantum mechanics there is a sense in which all observables, and in particular observables corresponding to every level of structure, are to be regarded as equal in the sight of God, as are different frames of reference, relativistically conceived. As I intimated earlier, quantum mechanics seems to be telling us that it is a classical prejudice to suppose that the world is not intrinsically structured at anything but the level of elementary particles, and their actions and interactions.

A final reason for preferring the connection view is that it produces a causal mesh with a topological structure of its own. Connections could be either symmetric or asymmetric, and the receptive face of causation would have the form of a directed graph providing a kind of scaffolding off which the rest of nature could hang. Both a theory of causation and a theory of consciousness must eventually grapple with issues involving the nature of space and its relation to time. The topology provided by connectivity gives hope for grounding a reduction of the facts about space and time, potentially increasing the explanatory power of the theory. The spatial assumption of such a reduction would be that there is *a causality condition on locality, not a locality condition on causality*. With respect to time, temporal succession and precedence would correspond in a structured way to asymmetries in relations of causal constraint.

9.10 The Theory of the Causal Nexus

The determination problem Assume we accept that causation is not fundamentally about causal production. What does it mean to say that, instead, causation is about constraint on a space of possibilities? What problem does the causal nexus resolve for nature?

I will frame the alternative to causal production through reference to the *determination problem*. The determination problem arises from the fact that the world's individuals each have many potential states. To be actualized, an individual must take on one, and only one, of these potential states. That is, it must become *determinate*. One can imagine the world's basic properties, say, mass, charge, and velocity, as mere potentials with many possible determinate values. The determination problem is to create a determinate world from these indeterminate potentials. Causation solves the determination problem.[v]

The determination problem does not necessarily have to be solved by a process through time. Introducing levels of constraint is another possibility. If one thinks of causal connection as an operator on a space of possibility, one can imagine that it is applied in the basic instance to basic determinable properties at a moment in time. If this first-level application does not yield a completely determinate state for the world, a second-level operator can be applied to the results of the first-level operator, and a third-level operator to the results of the second-level operator, and so on in layers until the total set of causal connections in the world produce determinacy. As I explain in detail here and in the next chapter, these successive applications can occur at successive levels of organization as easily as they might occur at successive moments of time.

In the classical scientific and commonsense picture, causation solves the determination problem almost at once: The interactions between basic particles and forces constrain them to have determinate states. This classical viewpoint is a two-level solution in the sense that the constraints on particle natures count as one level of constraint and that their interactions through forces count as a second level of constraint. After the second level of constraint the lowest level entities are determinate and there is no more need for causation: The determinateness of things at higher levels is a direct consequence of the determinateness of things at the lower levels.

Although intuitive, almost dangerously so, this classical conception is not an a priori truth. Nature might solve the determination problem in one or two levels, as the classical conception presumes, or nature might have to add further layers of causal connection before the determination problem is resolved. If that were true, it would be counter to classical views of the world, but not unsupported by evidence or wholly surprising. We actually have some a posteriori reasons from quantum mechanics to believe that the classical presumption is false and that the lowest levels of constraint leave the states of the lowest level individuals in the world indeterminate. The question of whether this quantum evidence is what it seems to be, or whether the classical view will win out in the end, is open to discussion and further evidence. If the classical conception were false in a world, it would imply that layers of fundamental causal relation above the lowest levels are needed to make that world's individuals fully determinate.

Overview The theory I develop below is a theory of the causal nexus. It allows us to model classical and nonclassical solutions to the determination problem, and it is explicitly agnostic about how many levels of causal connection are in the actual world. The theory's purpose is to provide a framework in which one could model many proposed answers. Thus perhaps causation solves the determination problem by taking one, two, or two hundred steps up the ladder of nature. From the perspective of the theory here, all answers are equally acceptable. Its concern is to allow the questions to be posed and to enable this by representing more general truths about what causation is and how it works.

My first step will be to give a very high-level gloss on the overall shape of the theory. I will do this by introducing a few basic definitions and by propping up an example of how, on the view of causation to be developed, the determination problem might be resolved for neural states at a middle level of nature. In a causal realist's world, there will *at least* be:

Definition 9.2: *A causal nexus* (pluralized as causal nexii)–A receptive connection binding two or more effective individuals.

Definition 9.3: *Effective properties*—Properties that contribute to constraints on the determinate states of a causal nexus.

Definition 9.4: *Receptive properties*—Connective properties enabling individuals to become members of causal nexii and to be sensitive to constraints on the state of nexii where they are members.

Definition 9.5: *Causal laws*—Laws describing restrictions on the composition of the causal nexus; that is, laws describing the compatibility, incompatibility, and requirement relationships between effective properties within a nexus.

These four commitments form the skeleton for a theory of nomic content and, therefore, of causal significance. A theory of causation will come from more fully articulating and tightening these skeletal ideas.

For a first pass at tightening these ideas, I am going to gloss a hypothetical causal life and causal context for an arbitrary neural cluster. The purpose of this first example is to gradually introduce the way of thinking suggested by the determination problem and embodied in the theory. The example illustrates some general principles and asserts some of the key concepts without introducing too much detail. The detail and explanation will come later. Also, it is not intended to be a proposal for actual neural causation.

How can we become accustomed to thinking in terms of the determination problem? Imagine a neural cluster NC that is one of sixteen such clusters NC_1 to NC_{16} densely interconnected in the brain. How might we understand their causal relations if the determination problem has not already been resolved at a lower level of nature? Before we can say much to answer this question, we first need a clearer way of thinking about what it asks, so before describing the relations between these clusters I define two new concepts.

The first concept is that of something having a state "considered independently" of its environment. The state of an individual *I*, considered independently of its environment, is the state it could be said to have if one took account only of the causal relations internal to it, that is, the causal relations between its own constituents. In the context of the determination problem, this is a way of asking whether the causal constraints holding solely between its constituents are strong enough to produce a determinate state for *I*. So, for a given individual *I*, even if *I* is in a determinate state given the whole causal situation in the world, there is a question to ask about whether it is determinate "considered independently" of its causal relations to its environment. This question can have either a yes or a no answer. We can therefore define:

Definition 9.6: *I* is in a determinate state when *considered independently* if, and only if, the causal relations belonging to the constituents of *I* entail that *I* is in a determinate state.

There are two conditions under which *I* would be determinate when considered independently. These two conditions are (1) its constituents are each already determinate considered independently or (2) the existence of *I* itself adds some causal relation among its constituents that makes them determinate. In all other cases, *I* would be *indeterminate* when considered independently.

Closely related to the concept of an individual *I* being considered independently is the concept of the states that are *independently possible* for *I*.

Definition 9.7: A state *S* is *independently possible* for *I* if, and only if, *S* is a state left open for *I* when *I* is considered independently.

If an individual *I* is determinate when considered independently, then there will be only one state *S* that is independently possible for *I*. However, if *I* is indeterminate when considered independently, then there will be more than one state *S* that is independently possible for *I*.

Given these definitions, suppose that *NC* and the other neural clusters are each in indeterminate states when considered independently. It follows that:

1. There are many independently possible states for each of them.
2. Considered independently, the number of possible joint states of the neural clusters is the Cartesian product $NC_1 \times NC_2 \times NC_3 \times \ldots \times NC_{16}$ of their individual independently possible states.

This is what it means to say that the determination problem has not been resolved for NC_1 through NC_{16}. In fact, if even one of the clusters were in an indeterminate state when considered independently then we could not say the determination problem was resolved for the group of clusters, as they are densely interconnected and we can assume their joint state is critical for other systems. If even one cluster were indeterminate when considered independently, then the joint state of all the clusters potentially would be indeterminate with consequences for any further systems whose behavior might depend on their joint state.

With this aspect of the determination problem understood more clearly, we can ask again, How might we understand their causal relations if the determination problem has not been already resolved at a lower level of nature? The purpose of a causal relation is to help resolve the determination problem so it seems that here there is work to do for a basic causal relation. Receptivity will stand in as this basic causal relation.

Please recall from the previous section that I am going to treat receptivity as a connection: Each instance of receptivity can be shared in common by multiple individuals. With this in mind, assume that NC_1 and NC_{16} share a common receptivity. Here, please consider their common receptivity to be a novel ontological factor not derivable from lower level conditions. Through sharing it they are bound together within a single causal nexus.

The theory attaches two kinds of significance to the sharing of this common receptivity between *NC* and the other neural clusters. First, each cluster is an individual in the nexus and there are conditions, described by causal laws, for cohabitation of a single causal nexus by multiple individuals. The existence of causal laws means that the states available to each neural cluster within the nexus are directly constrained by whatever effective states are available to the others. Second, their shared receptivity establishes the potential for them each to be part of a common receptive field with the others. Within this common receptive field their joint states could be constrained as a whole by interaction with external influences. The facts of the situation are depicted in figures 9.4 through 9.7.

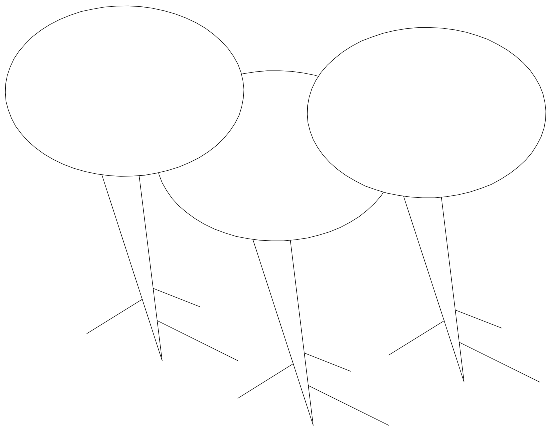
Figure 9.4 simply depicts *NC* as a neural cluster.

Figure 9.5 represents five independently possible states for the neural cluster *NC*, each state represented by a different shading, depicting the fact that *NC's* internal causal relations do not constrain it to a unique state. When a situation like this is true of an individual like *NC*, I say that the individual is indeterminate when considered independently.

Figure 9.6 represents a shared receptive connection between *NC* and other neural clusters. This connection represents a causal nexus that *NC* has entered into with the other clusters representing *NC's* receptive field. The other clusters sharing this receptivity provide an immediate environment for *NC* at its own level of organization, and *NC's* environment adds constraints to its state over and above those it has when considered independently of its environment. By taking on environmental constraints, *NC* may find that some of its independently possible states are no longer open to it.

Figure 9.7 shows the whole group subject to a common receptive field at a higher level of organization. Just as *NC* is a cluster with a receptive field of its own, one consisting of the other fifteen clusters to which it is connected, it is also part of a

Figure 9.4 A neural cluster *NC*



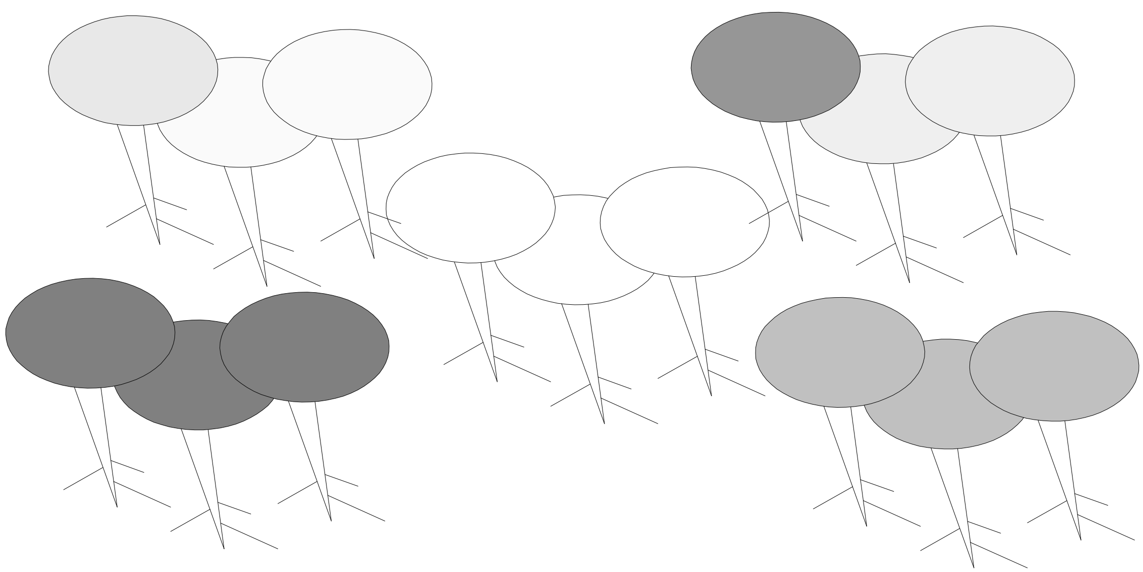


Figure 9.5 Indeterminacy in NC: Each shading represents a different possible state for NC when considered independently of its environment.

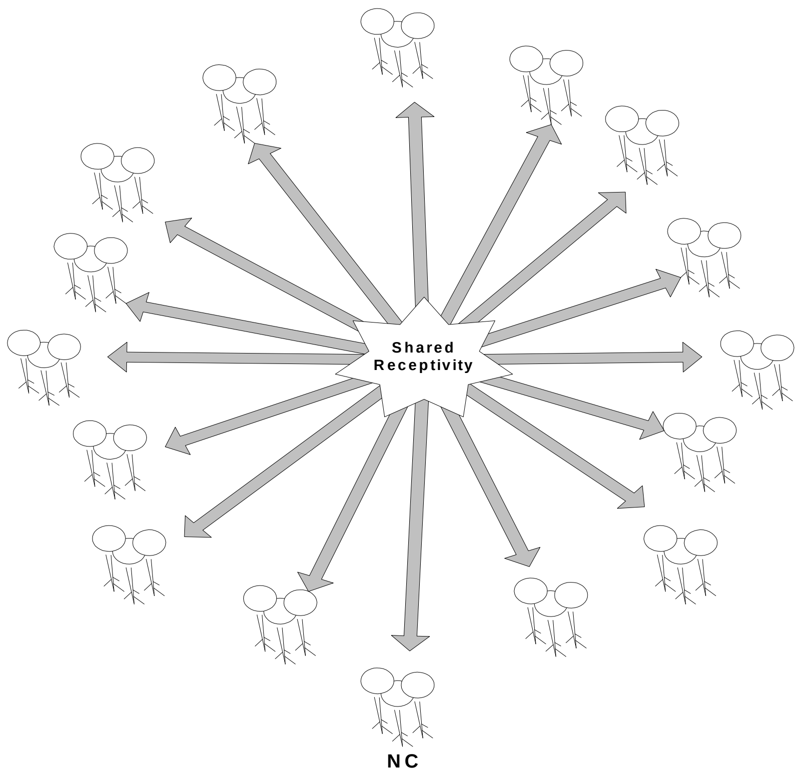


Figure 9.6 Direct causal influence between the different neural clusters arises through a shared receptive connection. The influence of the other clusters presents further constraints on the possible states open for NC.

collective supercluster emerging from the shared receptivity of the sixteen lower level clusters. The supercluster may have its own receptive field, enabling further environmental constraint on its state.

It is a basic tenet of this view that, as a consequence of the common receptivity shared between *NC* and the other members of the nexus, there is a common constraint structure that reduces the space of their possible joint states. Furthermore, in the context of its shared receptivity with the other clusters, *NC* is no longer being considered independently, and we can assume that the elimination of some possible joint states for the network of clusters results in the elimination of some of *NC's* independently possible states. For the sake of the example, assume that only one of *NC's* independently possible states remains in the set of permissible joint states. As a result, *NC* becomes

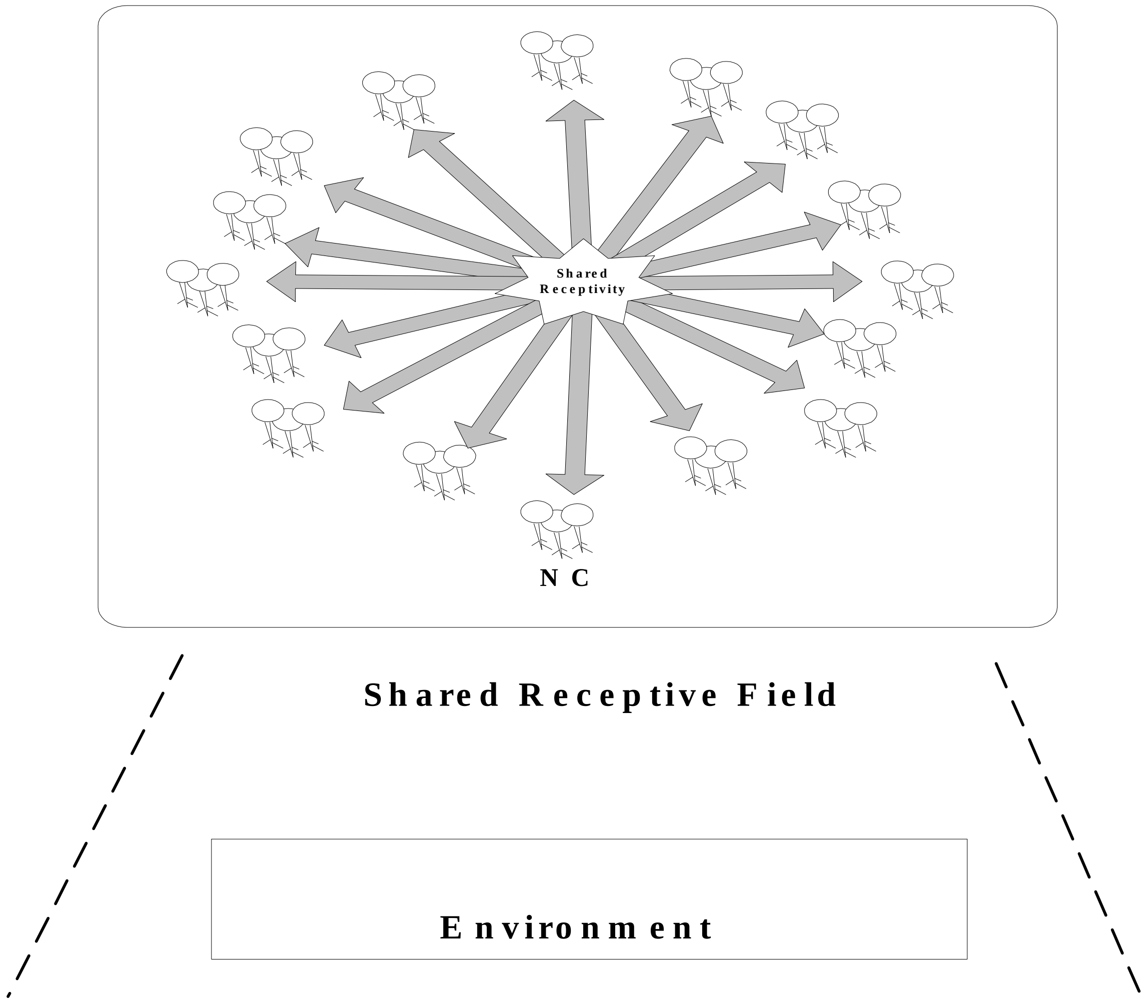


Figure 9.7 The existence of a shared receptivity establishes a common receptive field for the group of neural clusters.

determinate, and the determinate state that *NC* finally manifests is the result of influences active on its entire situation within the nexus: The shared receptive connection adds constraints to the possibilities for *NC* relative to what they might be otherwise.

<1>9.11 The Deep Structure the Causal Nexus</1>

<2>*Binding*</2> Having glossed the high-level story, I can begin to examine the low-level detail. Note here that the particular concept of “individual” being used by the skeletal commitments needs further definition. Because simplicity is the preeminent virtue guiding construction of this fundamental theory, I keep strongly to

parsimony constraints. My most primitive individuals are just the most primitive effective properties (e.g., Mass, Charge, and Spin) and receptive properties. In the theory these property instances are called level-zero individuals as illustrated in Figure 9.8.

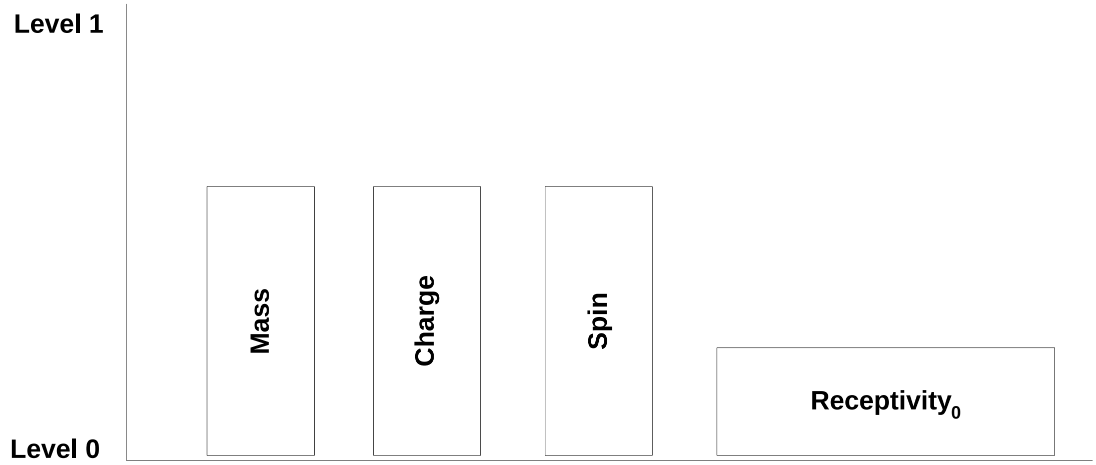


Figure 9.8 Four basic properties, three basic effective properties and an instance of receptivity, existing as level-zero individuals.

I develop a view whereby receptive connections are special *properties* whose instances can *bind* to more than one individual at a time. The individuals a receptive property binds, together with the receptivity, create a new individual. We can consider this new individual to be a level-one individual constituted by the binding of the level-zero individuals. This new individual is the one to whom the receptivity *belongs* in the more conventional sense of a property belonging to an individual. The level-zero individuals in general belong to the level-one individual constituted by their binding. Level-one individuals might be things such as the fundamental particles. Figure 9.9 illustrates the creation of this kind of complex level-one individual from the binding of the simple level-zero individuals.

Formally, if a two-place receptive connection *RP* binds to two primitive effective properties EP_1 and EP_2, together they form a higher level individual (e.g., a fundamental particle) that has as properties the receptivity *RP* and the effective properties EP_1 and EP_2. The principle generalizes for receptive connections of more than two places and, with respect to receptivity, for individuals at higher levels than level-zero (discussed later)[vi]. For example, in applying this principle to the previous discussion of *NC*, we would say that their common receptivity *binds* each of *NC* and its fellow neural clusters. Thus the sixteen clusters together come to constitute an individual that has the receptivity as a property, leading to the possible existence of a receptive field for the new individual.

However, I tread carefully, because any understanding of the effective and receptive properties must respect the special categorical interdependence between them. To represent this interdependence, I propose thinking of the properties themselves as having incomplete natures and needing to bind with individuals possessing the complementary kind of property to complete. This *binding relation* must be a unique kind of *internal* relation between the effective and receptive properties that allows for a kind of metaphysical completion of their essences. When incomplete

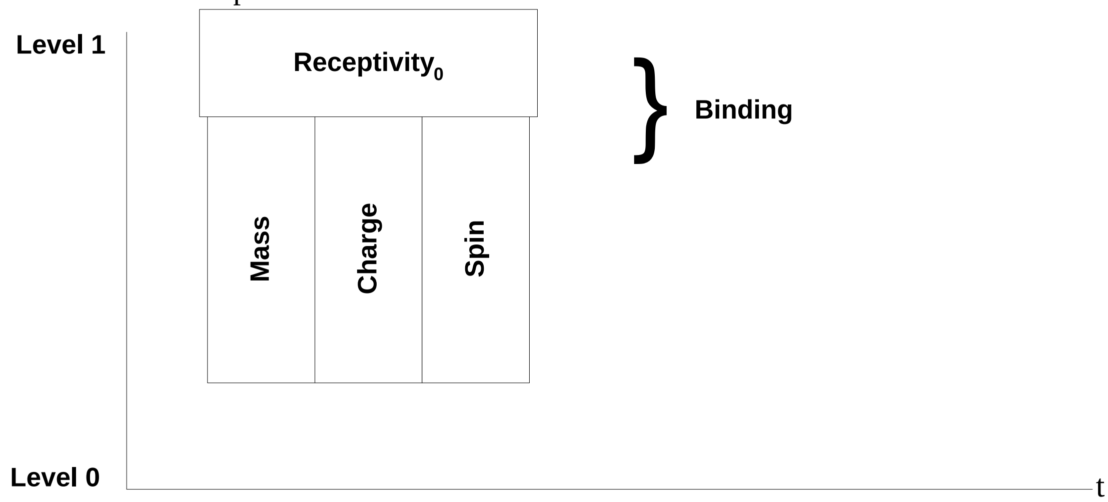


Figure 9.9 The level-zero effective individuals may bind to the level-zero receptivity, creating a level-one individual such as a basic particle to which they all belong.

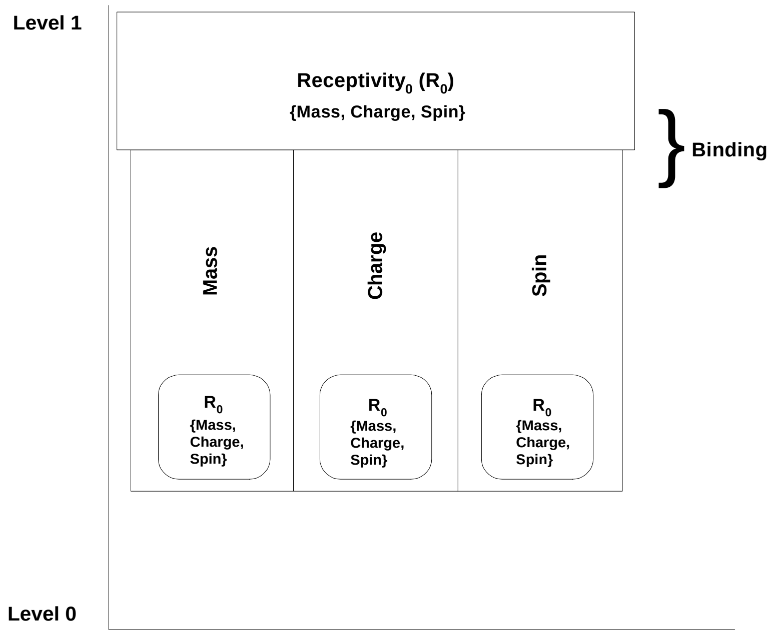
natures bind to one another, the binding achieves three things:

First, bound properties become *part* of the incomplete natures they bind to, making those natures more complete.

- Second, a collection of bound natures containing more than one effective individual becomes a *causal nexus*.
- Third, binding supports a kind of transitivity, and so it provides the mechanism of causation by enabling the penetration by which distinct effective natures can *condition*, *include*, or *exclude* one another.

The thesis that completion through binding enables a kind of transitivity is important and it is illustrated in Figure 9.10. In Figure 9.10 the three effective properties Mass, Charge and Spin are shown as taken up, through binding, into the completion of the receptivity $\mathbf{R_0}$, which in turn is shown as part of the completions of the three effective properties. Through $\mathbf{R_0}$ each of the effective properties, or some part of their individual determinable natures, becomes part of the completion of the other two effective properties.

To illustrate the importance of transitivity, imagine that through binding some part of an effective nature E_1 becomes part of the completion of a receptive nature *R*. For the example, assume that E_1 is already complete so that *R* does not become part of its completion. As a connective property, *R* becomes part of the completion of a second effective nature E_2, and, because E_1 is part of the completion of *R*, by transitivity E_1 becomes part of the completion of E_2.[vii] *R* then constitutes an asymmetric connection between E_1 and E_2. It is at this point that the internal relations between effective properties become relevant. One effective property cannot form part of the completion for another effective property unless



<FN> Figure 9.10

An illustration of how binding achieves completion by having the distinct receptive and effective essences penetrate one another, and also how completion supports a kind of transitivity in which distinct effective properties can become parts of one another's completions.

the nexus satisfies the conditions of their internal relations. For example, if through a shared receptivity *R* an effective property E_1 becomes part of the completion of a second effective property E_2, and a potential value for E_2 is incompatible with the value of E_1, then that potential value will be eliminated from E_2*'s* determinable nature. This is a case in which I say that E_1 *conditions* E_2.

The introduction above is enough to suggest the importance of transitivity, and there will be more detail about conditioning later. Let us now continue the introduction by focusing on the fundamentally important ideas of incomplete natures and their completion. Recall that a determinable is a general property such as *redness,* which can have a variety of possible shades, called its *determinates*. Similarly, *shape* is a determinable property that can have a variety of determinates: triangularity, squareness, rectangularity, hexagonality, and so forth. Physical properties such as charge are also determinables with determinate values such as positive and negative. Incomplete *effective* natures and their *completion* follow the model provided by the traditional concept of a *determinable* becoming more *determinate*. Effective properties are determinables, and their completion is a process of their becoming more determinate.

One can think of an incomplete effective property as a determinable of a sort. It is an abstract entity that contains a propensity within it to become one of its determinates. Depending on the character of the determinable, these determinates are shapes or forms or qualities or quantities that the abstract nature may take on completion.

As for the receptive properties, I propose thinking of incomplete receptive properties as neutral essences with a kind of inherent openness representable as a set of "slots." These "slots" accept effective individuals to which the receptive property binds. To give some imagery to it, think of effective individuals as cans of Coke and receptivity as the thin transparent plastic that binds cans of Coke into six-packs. The loops in the plastic that bind the Coke cans are like the slots in the receptivity to which natural individuals bind. The idea of a "slot," then, is a metaphorical way to represent a receptive connection's *carrying capacity*. In this book, I always represent a receptive connection as having a discrete and finite number of slots, although I believe the theory could be extended to instances of receptivity with a nondenumerable capacity.

Whereas the plastic binding of a six-pack merely curls around Coke cans, a receptive connection binds individuals in a much deeper and more penetrating way. Binding is an internal, metaphysical relation between abstract essences (i.e., the otherwise incomplete effective and receptive natures). When effective and receptive natures bind, I say that the corresponding receptive slots become *saturated* ("saturation" is analogous to the plastic loop being "filled") by the effective determinable and do not merely hook around it externally. The saturation constitutes a merging of the two natures into a more complete nature.

In binding, each incomplete member becomes more complete by taking up some part of the nature of the thing to which it binds.[viii] So some part of the effective determinable becomes part of the receptive openness, and some part of the receptive openness becomes part of the effective determinable. If two or more effective natures bind to the same receptivity, then I say that they share a common receptivity, and the new entity forms a causal nexus.

Definition 9.2 (expanded): *Causal nexus*—Two or more nonneutral determinable individuals (i.e., effective individuals) sharing a common neutral essence (i.e., a common receptivity). A causal nexus must have exactly one receptive connection binding more than one effective individual.

For reasons I will discuss in detail in the next chapter, the unbound incomplete natures are abstracts, and so the causal nexus is the basic kind of individual inherent in nature. If this is correct, it follows that instances of pure effective or receptive properties do not exist in nature, and so there are no pure level zero individuals realized in the natural world. They are only metaphysical abstracts. Instead, nature contains effective/receptive complexes.

In some (shallow) respects, the relationship between effective and receptive properties is like the relationship between the front and back of a wall (assuming for the sake of analogy that "front" and "back" name absolutes). The two faces of a wall are distinct, just as receptivity is distinct from effectiveness. Yet a wall cannot exist without having both a front and a back, just as a natural individual cannot exist without both effective properties and receptiveness. Also, in a generic sense, the front and the back of a wall are necessarily connected: It is impossible that the front of a wall should exist without a back of the wall existing, and vice versa. The relationship is one of mutual necessity and is neither supervenience nor identity, just as the existence of effective properties and receptivity mutually necessitate one another, although their relationship is neither one of supervenience nor identity. Also, it is natural to think of the front and back of the wall as being two aspects of the wall, just as it is natural to think of effectiveness and receptiveness as two aspects of a natural individual. Yet underlying the two aspects of the wall are two properties possessed by the two faces of the wall, one face which has the property of being its front and the other face which has the property of being its back. Similarly, the effective properties and receptive properties are distinct properties underlying the different aspects of an individual's nomic content.

Notation My notation models these effective/receptive complexes. An incomplete receptive/effective complex is a nature denoted by expressions such as *EP*(_,_,....,_), where *EP* by itself would denote an effective property (or an individual with effective properties); (_,_,….,_) by itself would denote an open receptivity; and *EP*(_,_,....,_) denotes the effective/receptive complex created by *EP* binding to the receptivity. Returning to our Coke metaphor, *EP* is like a can of Coke, and the underscores in between the parentheses represent unfilled loops in the plastic binding used to hold the six-pack together.

Because of their internal relations of compatibility, incompatibility, and inclusion, effective individuals have a feature that is not present in the image of the six-pack of Coke: The bound effective individuals each contribute to a set of state constraints on the nexus (on the six-pack). These state constraints determine what determinate features the members may have. Imagine that each can of Coke is initially a blank tin with many different designs potential within it and that what design finally graces the can depends on which other cans are bound into the six pack. As cans are bound with one another, definite features begin to appear: the Coca-Cola logo begins getting more and more distinct, the ingredients list begins to fill out, and red appears. The appearances of the can's design features are like the determination of an individual's effective properties.

The state of the nexus is the joint state of its members, so the set of state constraints to which each effective individual contributes is a set of constraints on the joint states of the members of the nexus. Depending on the nature of the shared receptive connection, this constraint placement might be *asymmetric* or *symmetric*. If it is an asymmetric connection, then the constraints are structured so that one or more individuals constrain the states of one or more others but do not have their states constrained in return. If the connection is symmetric, then the constraints on the state of the nexus may affect every individual bound to the connection.

I represent the *asymmetric* binding of an effect tive property EP_2 to an effective/receptive complex such as $EP_1(\_)$ as $EP_2 \Rightarrow EP_1$, signifying that EP_2 has saturated the open slot in the effective/receptive complex denoted by $EP_1(\_)$ and is now constraining EP_1. If EP_1 and EP_2 share a *symmetric* receptivity that creates a symmetric constraint between them, I abbreviate this as $[EP_1.EP_2]$ to reflect the reciprocal relation between the effective properties in sharing the receptivity. Complexes of more than two effective properties all sharing a common symmetric receptivity would be represented by notations such as $[EP_1.EP_2.EP_3]$, $[EP_1.EP_2.EP_3.EP_4]$, and so forth.

Primitive natural individuals My proposal for understanding primitive natural individuals is that the primitive level-zero natural individuals bind together to compose the most basic effective/receptive complexes such as $EP_2(\_)$, $EP_2 \Rightarrow EP_1$, and $[EP_1.EP_2]$: i.e., The pure effective determinables (e.g., EP_2) and the pure open receptivities (e.g., (_, _)) bind to become the basic effective/receptive complexes. As stated earlier, these pure level-zero individuals are abstracts, and are never found in a pure state in nature. It is as if the government prohibited the Coca-Cola Company by law from selling single cans of Coke or distributing completely unfilled plastic binders. On this analogy, level-zero individuals are like loose singles of Coke and empty plastic binders that can never make it out of the warehouse and into the marketplace. Instead, it is essential that level-zero individuals be bound to one another in complexes where the receptivity is saturated and the determinable can be made more determinate.

These complexes are *pure property complexes* constituted by (1) one or more effective determinables and (2) a receptive openness binding them directly to itself and indirectly to one another. Furthermore, when a level-zero instance of receptivity has all its slots saturated, the resulting causal nexus such as $[EP_1.EP_2]$ constitutes the creation of a *level-one individual* made from the level-zero individuals by the special binding relation holding between their natures.

Definition 9.8: A receptive connection is *complete* if, and only if, it does not contain an open slot.

Definition 9.9: *Level-one individual*—A completed receptive connection consisting of a level-zero receptivity binding level-zero effective properties.

Causal laws The resulting ontology is an event ontology in which the actualization of an individual is the fundamental natural event and in which individuals may be internally linked into processes. Individuals themselves are pure property complexes (i.e., there are no enduring substances). Descriptions of the restrictions on the composition of a causal nexus are *causal laws* (i.e., laws describing the possibility of immediate causal connection between individuals). Causal laws, then, are *laws of completion for a causal nexus*. I introduce "causal laws" as a technical term here. Causal laws are not descriptions of regularities in the instantiation of properties through time, which are what we traditionally have called the laws of nature or laws of physics.

I illustrate causal laws by recalling the imaginary example of the two coins that must be flipped together and that share a joint state. Recall that the constraint on their joint state is that they both have to land heads up or both tails up; one cannot land heads up and the other tails up. Using the apparatus being introduced here, a coin's potential to land heads up or tails up is analogous to two determinate states of a determinable property that the coins may have. Call this determinable property its *landing property*. The constraint on the joint state of the coins would be associated with (1) the existence of a shared symmetric receptivity binding the two coins within a nexus and (2) a causal law describing how their individual landing properties are mutually compatible or incompatible. In this example, the causal law describes the conditions under which different instances of the landing property can coexist within the nexus. A causal law sufficient to describe the behavior would be: *A heads-up value of the landing property is compatible only with another heads-up value*.

Effective natures sharing a receptive connection contribute to global constraints on the state of the nexus. The contributions of different members of the nexus may be seen as either *completely* or only *partially* constraining other members of the nexus. The example of the two coins illustrates at least potential complete constraint in the sense that any determinate value either coin takes for its landing property completely determines the value the other coin must take. It is also a case in which there are two independently possible states for the linked coins together. Therefore, the definite state they take on must be determined by wider conditions to which they individually or collectively become bound.

Partial constraint is more relaxed than complete constraint. If members partially constrain one another, their copresence within the nexus means that particular determinate values they may take on may exclude some, but not all, of the latent potentialities within the determinable natures of other members. To illustrate further, imagine that we had two six-faced dice similar to the two coins in that they are bound to a common symmetric receptivity. This means that there is a constraint on their joint state. Imagine also that the causal law describing the restrictions on the landing properties of these dice is that one die landing with an even number on its face is compatible only with the other die also landing with an even number on its face. In contrast to the compatibility relations between values of the landing property on the coins, the value of the landing property of one die would only partially constrain the value of the landing property of the other die. So a die landing with a six on its face leaves three possibilities for the other die: two, four, or six. Even given the value of one die, the value on the other die is left indeterminate.

What if wider conditions binding one of the coins or one of the dice were to fix the value of that coin or die, say forcing a coin to land heads up or a die to land with the number two face up? The coin whose landing property was fixed by other circumstances to be heads would fully constrain the other coin to be heads also (If the coins are taken to be analogous to entangled particles, we can imagine this as a circumstance in which one of the particles is measured.). The die whose landing property was fixed by other circumstances to be two would partially constrain the other die, leaving only two, four, and six as possible values for its landing property. Whenever one property or individual in this way fully or partially constrains the state of another, I say it *conditions* that other property or individual, where this conditioning corresponds to making the determinable more determinate by narrowing the set of potentialities within its nature. Notice the role receptivity plays by connecting natures of effective determinables so that they may condition one another:

> *Receptivity itself acts as the causal connection. Nature needs no other ontological grounding for the causal connection.*

Higher-level individuals Because the causal connections between individuals at a single level might only partially condition one another, there might be a hierarchy of natural individuals. The possibility for further stratification would exist whenever the effective state of the level-one individual was still indeterminate in some respects. In general, partial determination would occur if a determinable property *EP* held multiple determinate potentials in its nature, for example, 0, 1, 2, and 3, and if it bound with a receptivity whose other bindings exclude only some of those values, for example, 0 and 1. In such a case, the level-one individual would still have a determinable state containing values such as 2 and 3 as possibilities for *EP*.

This is like the example of the two dice. A roll of the dice does not, by itself, contain enough constraint to determine the joint state of the dice or even the individual states of either of the dice. However, it is possible that the individual that is the two dice together could belong to an environment of other natural individuals whose presence adds further constraints and succeeds in determining the joint state of the dice.

The relevant indeterminacies correspond to remaining incompletenesses in the effective nature of the level-one individual. In such a case, the individual is still an abstract in some respects and, as such, is still a complex of potential rather than a fully concrete determinate. The determination problem is not yet resolved for that individual, and causation has more work to do. To become fully determinate, the level-one individual would need to bind within a causal nexus with other level-one individuals to form a *level-two* individual analogously to the way that the level-zero effective properties form level-one individuals.

Figures 9.11 and 9.12 illustrate the creation of a level two individual in this manner. Figure 9.11 shows two level-one individuals, again visualized as some sort of elementary particles, at least one of which we can assume is indeterminate when considered independently. Figure 9.12 shows a level-one receptivity binding them together into a level two individual, with that receptivity belonging to the newly constituted level two individual. The earlier remarks regarding transitivity continue to apply, and so we can assume this new nexus has constraints of its own that help resolve the determination problem.

The general idea here suggests an intuitively plausible principle linking completeness with determinateness:

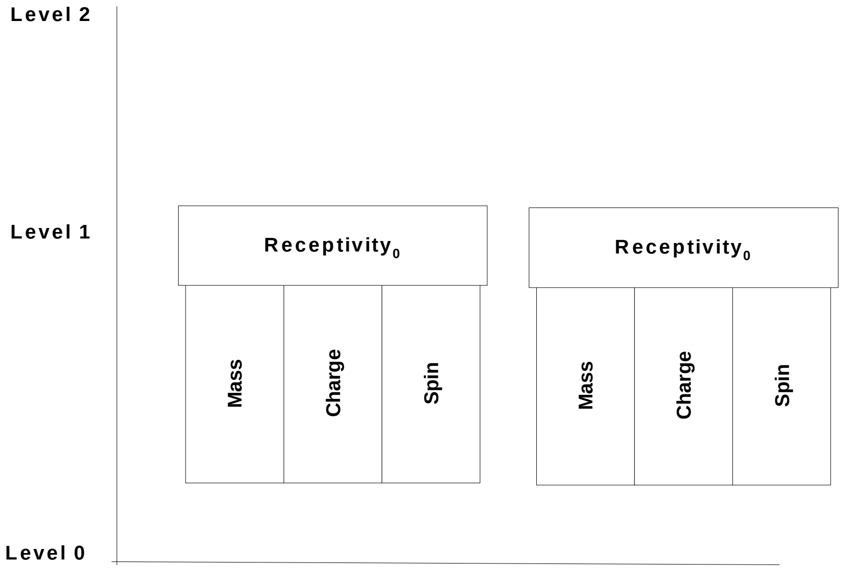


Figure 9.11 Two level-one individuals visualized as elementary particles of some sort. Their states are not represented, but assume that they are indeterminate when considered independently.

> *Determination indicates completion.* When a determinable nature is complete, it is fully determinate.

The principle that determination indicates completion suggests two further definitions:

Definition 9.10: An effective property is *complete* if, and only if, it is in a fully determinate state.

Definition 9.11: A compound individual is *complete* if, and only if, all of its member individuals are complete.

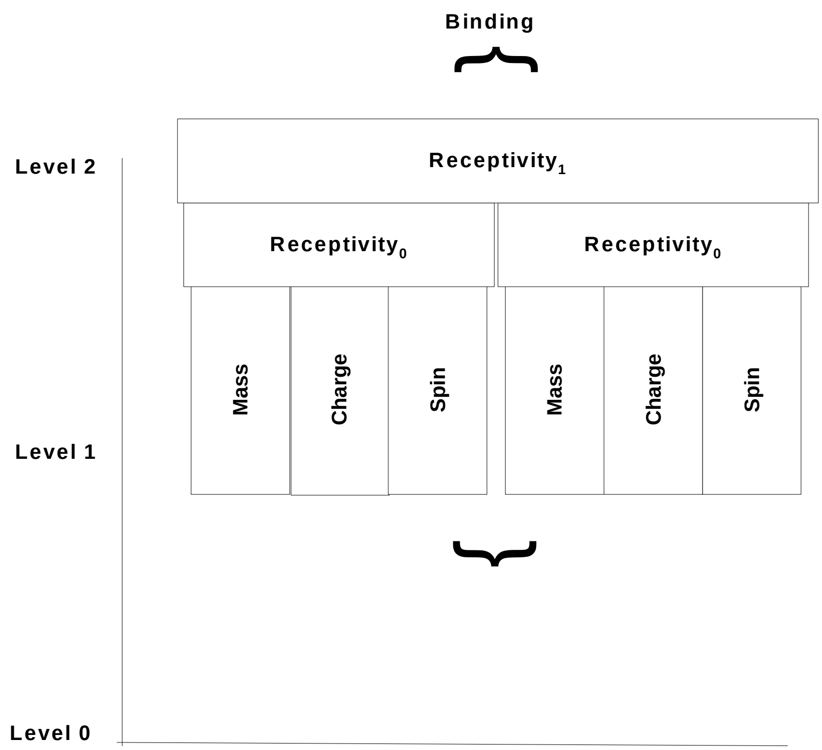
The principle that determination indicates completion also suggests a basic causal postulate:

> *The principle of maximal completion.* Individuals seek completeness.[ix]

The principle of maximal completion names a tendency without implying that every individual achieves completeness or is complete at all times. It is a technical expression of the earlier sentiment that, for all we know, existence is something toward which all things tend. The process of seeking completeness may be seen as competitive, and the successful determination of some individuals may preclude the successful determination of others.

By introducing the principles so far, I am incrementally building a dipole vocabulary linking the ideas of abstractness, indeterminateness, incomplete natures, and potentiality on one pole while linking the ideas of concreteness, determinateness, completion, and actualization on the other pole. A concrete event can be seen as the completion of an atemporal process of becoming moving an individual from one pole to the other. Determination is an actualization, a coming into the world, for a bound property complex. Furthermore, in building this vocabulary, I am not only linking the concepts at each pole and contrasting the two poles, but I am also making their application, in principle,

Figure 9.12 The two level-one individuals from Figure 9.11 are bound to a common level-one receptivity within which they may become more determinate. This nexus constitutes a level two individual to which the level-one receptivity belongs.



a *matter of degree*. In the next chapter I discuss how these things can be a matter of degree when I explore the link between possibility and actuality.

Here is an example of the concepts at work in a Newtonian world. Consider the classical properties of Mass, Charge, and Velocity. The present theory holds that these would be basic effective properties and, therefore, level-zero individuals in the classical world. They would be found as members of effective/receptive complexes, where they share a common receptivity, creating level-one individuals. Let P_1 be such an individual and be represented by the notation [Mass.Charge.Velocity]. P_1 would be a basic particle.

The instance of receptivity binding the instances of Mass, Charge, and Velocity within P_1 is now complete. Recall transitivity: When an instance of a symmetric receptivity such as P_1*'s* binds two or more effective properties, it becomes part of the completion for all of them, whereas, through the same operation, they become parts of its completion, too. So, for example, in a [Mass.Charge.Velocity] individual such as P_1, Charge is part of the completion of the receptivity, which is itself part of the completion of Mass and Velocity. By transitivity, each of these effective properties likewise becomes part of the completion of the others.

These effective natures, precisely because they are *effective* natures, must share relations of intrinsic compatibility, inclusion, and exclusion with one another. The placement of these restrictive relations has the effect of determining under what conditions an effective property may properly form part of the completion of another effective property, thereby placing restrictions on the copresence of effective properties within a single nexus. On this view, stable particles such as P_1 are those property complexes that contain effective properties with a determinate set of values that are highly compatible or, equivalently, properties with a value set where the values minimally constrain one another, implying that Mass, Charge, and Velocity are in some sense highly compatible properties that form a stable nexus.[x]

Using these ideas, one can give a metaphysical account of what an *immediate causal interaction* is by viewing it as the creation of a level-two individual from one or more incomplete level-one individuals. Let us say that the particle P_1 has a second order property of *acceleration* that is not made determinate by conditions internal to the P_1 nexus. This implies that P_1 is not complete. Let us also say that its acceleration *is* made determinate by these conditions *plus* the magnitude of a certain force F at the region of space occupied by P_1. Resolving the determination problem requires P_1 to receive the constraint associated with this force.

P_1 has a receptivity belonging to it and further constraint may come to P_1 through the receptivity belonging to it. However its receptiveness is only potential until P_1 itself enters into a causal nexus defining its receptive field, i.e., providing the context in which further constraint may be received. There is no problem here. Although P_1 itself is a causal nexus of individuals at one level, that does not preclude it from becoming part of a causal nexus at another level. .

P_1's receptive field will consist of other individuals from whom it receives constraint through a shared receptivity, so to realize its potential for having a receptive field, there must be this distinct receptivity binding P_1 into a higher level causal nexus. We use $P_1(\_)$ to represent an instance of receptivity bound to P_1's nature. This receptivity is a level-one receptivity *binding* to P_1, and it is distinct from the level-zero receptivity *belonging* to P_1, This irreducible higher level receptivity establishes P_1*'s* receptive context and thereby allows nature to redress incompletenesses in its nature. The other members of this new nexus will constitute what other individuals, if any, are in P_1*'s* receptive field.

To deliver constraint to P_1, the force F must saturate the open slot in $P_1(\_)$. If we presumed that the force F's magnitude is not affected by P_1, we would represent asymmetric constraint with the formula $F \Rightarrow P_1$. The nexus $F \Rightarrow P_1$ is a level-two individual representing the action of the force on that particle at that region of space. P_1 is a level-one individual containing the property of *velocity,* and the new individual makes the second-order property of *acceleration* determinate for P_1. In other words: P_1 is receptive to *F; F* is in the receptive field of P_1. If we presumed that the magnitude of the force also depends to some degree on P_1, we would model the symmetrically connected level-two individual as [P_1. *F*]. This model of direct interaction as the creation of a new level of individual in nature is illustrated in Figure 9.13.

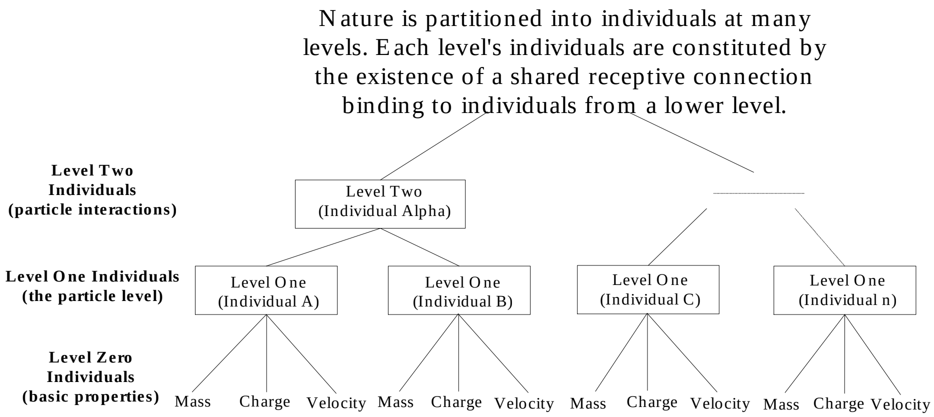


Figure 9.13 Levels of fundamental causal connection in nature may ascend as high as necessary to ensure determinateness.

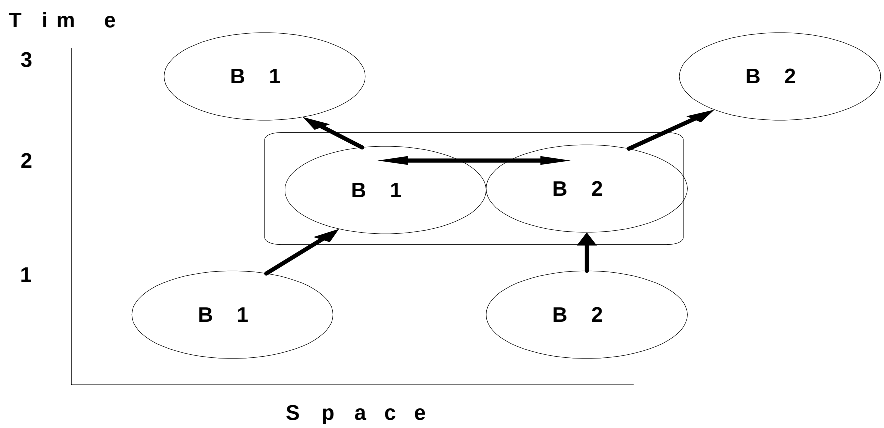
We can understand a simplified model of billiard ball causation in a similar way. Imagine that billiard balls are continuously dense spheres with four properties: mass, velocity, shape, and direction (i.e., each ball is an individual of the form [mass.velocity.shape.direction]). If there are two billiard balls, *B1* and *B2,* with *B1* traveling toward *B2,* one way to understand the causal situation is depicted in figure 9.14.

<FN> Figure 9.14 </FN> <FC> Two billiard balls colliding with one another. </FC>

B1 and *B2* are causal processes, meaning that each temporal stage of the billiard ball shares an asymmetric receptive connection to the previous stage. The single-headed arrows connecting the different temporal stages of the billiard balls represent these asymmetric receptive connections in the figure. Through these asymmetric connections, the immediately earlier stage of a billiard ball constrains the state at the later stage without being constrained in turn (the earlier stage can be seen as in the receptive field of the later stage, but not vice versa). In the first time slice of the figure, *B1* has a certain velocity and direction that are taking it toward *B2*. The collision between *B1* and *B2* creates a natural individual of which they are members and that exists only in time 2.

This new natural individual, the collision, represents a symmetric interaction between *B1* and *B2,* depicted by the box around the billiard balls and the twoheaded arrow between them. This adds a new constraint in addition to the asymmetric constraint each ball has to its previous state (*B2,* as well as the earlier stage of *B1,* is in the receptive field of *B1* at time 2). The total situation forces the state of each ball to be compatible both with its own previous state and also with whatever the current state of the other ball becomes. The constraint structure results in a new velocity and direction for each ball, with the consequences of these changes seen in time 3, where the balls are separated but still must take on states compatible with their own previously established states.

This treatment of the relation between the effective properties, the receptive properties, and natural individuation makes sense of some of the traditional views about receptivity. For instance, the medieval conception of God, used by Locke, as an entity that is *above all passive power* is inherited from the theological intuition of God as being intrinsically complete, whereas the created world is somehow inferior to and dependent on God's nature. This situation gets represented straightforwardly by introducing *God* as a complete nature



and the world *W*(_) as an incomplete nature and postulating an asymmetric binding *God* ⇒ *W* that represents the asymmetric flow of effective constraint from God's nature to the world. Furthermore, the intuitive oddness of thinking of receptivity as a kind of *passive power* is removed, as it is more natural to think of it as a kind of *openness* bound to the nature of effective determinables than as a kind of *power*.

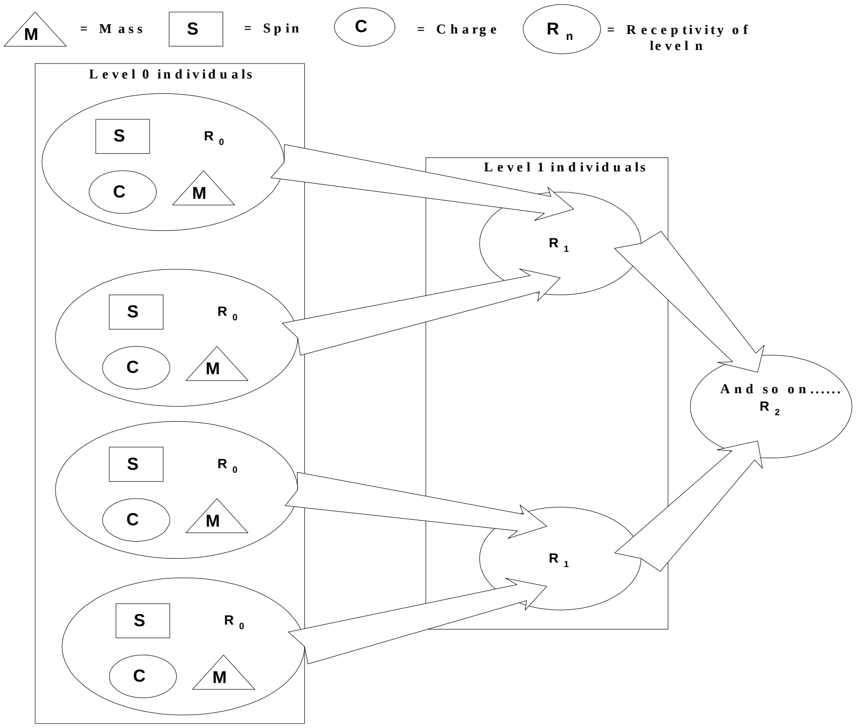
In the Newtonian picture of the world, interactions are modeled as level-two individuals consisting of the binding between a particle and a force. This is all the stratification we would ever need in a classical world, but there clearly is no *metaphysical* reason that worlds should be so shallow. So far, there are level-zero individuals. These are the fundamental physical quantities and the fundamental receptivities. There are also level-one individuals. These are the bindings of these physical quantities with level-zero receptive connections to form particles and fields of force. Finally, there are the level-two individuals, and these are the bindings of particles with fundamental forces. This is a clean and simple picture that solves the determination problem quickly and intuitively; however, this classical view of the world is not a correct view of the world. Certain features of quantum mechanics (such as quantum entanglement) at least suggest that the actual world really is more richly structured than this Newtonian picture suggests. This opens up the possibility of a nice inductive definition of natural individual:

Natural individual, base case: Any primitive effective or receptive property is a level-zero natural individual.

Natural individual, inductive case: Any set of natural individuals of level N bound into a completed receptive connection constitutes a natural individual of level $N+1$.

This inductive definition allows the world potentially to be a place with a great depth of individuals corresponding to many layers of binding and completion before full determinateness is achieved. Each individual would have an irreducible component, its receptivity, and a set of reducible components, the lower level individuals that are bound by its receptivity. Imagine that there were plastic binders that could turn six six-packs of coke into a thirty-six-pack and other binders that could create two-hundred-and-sixteen-packs from six thirty-six-packs, and so on. Figure 9.13 and figure 9.15 each provide a way to picture such a world, with figure 9.15 emphasizing the irreducible nature of each receptive connection.

Finally, I emphasize that I am introducing the term *natural individuals* as a technical term and that they do not correspond in any direct way to the perceptual and conceptual individuals we speak of in daily life. I even take it to be a substantial empirical question as to whether the individuals within a successful scientific theory are natural individuals in the sense that I have proposed. For example, societies may appear as individuals within sociology, and galaxies may appear as individuals within astronomy, but it does not follow that they are *natural individuals*. The *natural individuals* above level-zero are individuals in virtue of the fact that they have a special, unitary causal nature. They each consist of an irreducible receptive connection through which their components contribute to a set of global constraints on their joint state, and they are capable of having receptive fields of their own. They are "natural" individuals because they have a



9.15 Each natural individual at each level has its own unique and fundamental instance of receptivity.

special ontological unity constituted by the merging of their constituents' natures, facilitated by the receptive connections.

9.12 Laws of Emergence for Higher Level Individuals

The model introduced in the preceding section implies that levels of nature are strongly emergent and that each level of nature is a configuration of individuals at the previous level. The configuration consists of a set of irreducible receptive connections, each of which binds a select group of individuals at its own level into a higher level individual. We can describe the components of the natural order as follows:

1. There are natural individuals. Above level-zero, each natural individual of level *n* is analyzed into

    A set *S* of natural individuals from level *n* – 1. *S* contains exactly one irreducible receptive connection *R* of level *n* – 1 and arity *k*. *R* is appropriate for binding with the natural individuals at its same level. *S* also contains a group of size *k* of other individuals from level *n* – 1.

    An exhaustive assignment of natural individuals from *S* to slots of *R* under a primitive *binding* relationship.

    A set of independently possible states for the natural individual at level *n* that results from the binding of *R* with the other members of *S*. If this is a singleton set, the natural individual is *determinate*. Otherwise, it is *indeterminate*.

2. There are levels of nature. Each level of nature *n* is a configuration of natural individuals of level *n*. Configurations of natural individuals are distinguished by

    The number and kind of irreducible receptive connections of level *n* – 1 that have emerged and which belong to the individuals of level *n*. Recall that these receptive connections *bind* individuals at their own level but *belong* to the individual of the higher level that emerges because of the binding.

    The bindings through which individuals of level *n* – 1 are selected and assigned to the receptive connections of level *n* – 1.

    The possible states for the world given the emergent constraints associated with the configuration at level *n*.

The inputs into the configuration of individuals at level *n* are the natural individuals of level *n* – 1 and their possible states. The possibility of a new level comes from the emergence of receptive connections also of level *n* – 1 able to instantiate new constraints by binding the individuals at level *n* – 1 into level *n* individuals. The result of the configuration is a new set of individuals, each with their own possible states. The possible states of these new individuals are a selection from the joint independently possible states of their members according to a set of constraints corresponding to their internal relations of inclusion, exclusion, and compatibility, and therefore present a new (smaller) set of possible states for the world. Figure 9.16 illustrates levels of nature filtering possible states of the world.

The key question is: By what rules are the configurations of each level chosen? From a purely combinatorial point of view, for any given level of nature one could construct an enormous number of possible configurations for the next level. If the causal significance view of causation is correct, there must be some way nature chooses one configuration over another. These are laws of emergence for higher level individuals.

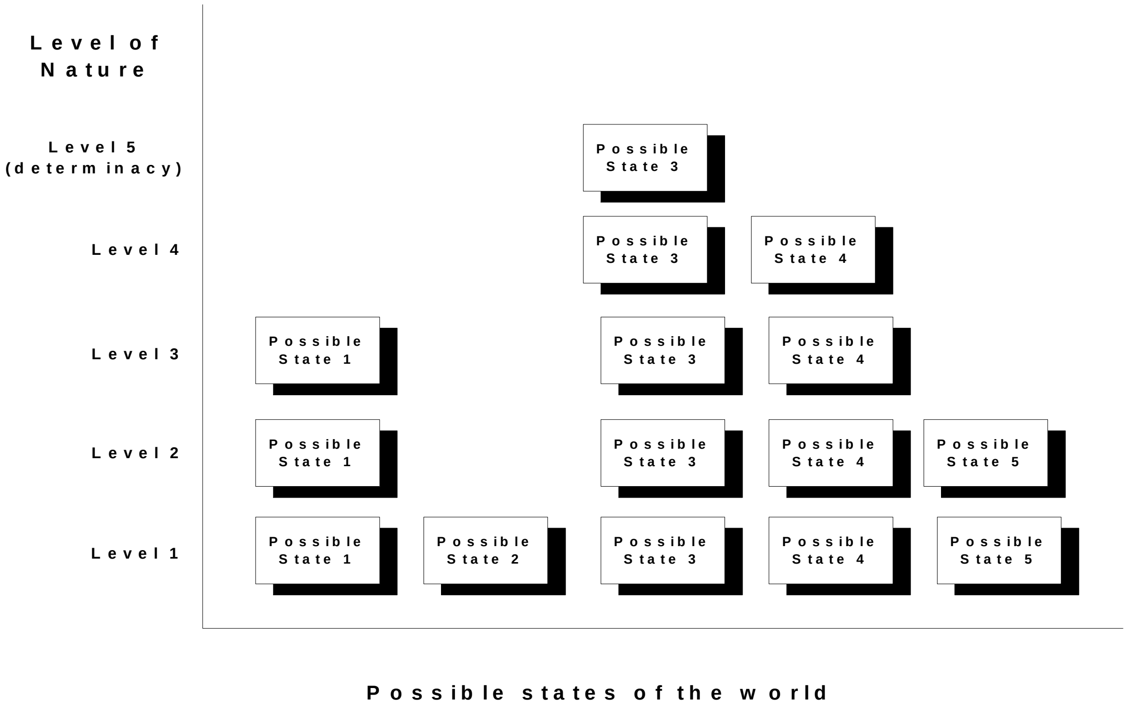


Figure 9.16 At each level of nature the emergent causal constraints filter out some possible states of the world. New levels cease to emerge after the level where the world is in a determinate state, here depicted as level five.

One rule is obvious: There must be indeterminacy in the lower level for a higher level to emerge at all. Without indeterminacy in the lower level, the determination problem is solved, and there is no need for further causation.

If there is indeterminacy to resolve at the lower level, then there is need for further causation. The alternative configurations for the emergent level will have properties of their own, determined by the states of the individuals that constitute them, and it is natural to suppose that the choice among configurations would be a function of their properties. Recall that each constituting individual has a number of independently possible states. In considering how or why some configurations might be preferred over others, reflection suggests two principles of interest to nature that could be relevant:

1. The principle of maximal completeness.
2. The principles of thermodynamics.[xi]

We can evaluate the set of independently possible states for a given individual for both its degree of completeness and the level of entropy within it. With regard to entropy, each independently possible state of each individual will have a degree of entropy, and we could measure the entropy for the individual by taking an average of the entropy of its independently possible states. The entropy of the configuration would be a function of the entropy of the individuals within it.

With regards to completeness, the principle of maximal completion says that determinateness indicates completeness. The determinateness of the configuration is a function of the possible joint states of the individuals within it. The fewer possible joint states a configuration allows, the more determinate it is.

Having said all this, I cannot propose a concrete law for the emergence of configurations at higher levels. Yet it seems natural to suppose that the right law might be a function involving nature's dual concerns for maximizing entropy and completeness. That is, given a configuration of individuals at one level, a configuration of individuals at the next level might emerge according to some function of its entropy (as measured by thermodynamics) and its completeness (as measured by determinateness). The precise form of the law could be deterministic (choosing the "best value" along the dimensions) or probabilistic (weighting a probability density function using a measure on the dimensions) and may use both factors or choose one as trumping the other. In any given world, it would be an open question what the precise form of the emergence law(s) would be. This leaves open six possible classes for the laws governing the emergence of higher level individuals:

	Deterministic	**Probabilistic**
Use entropy and completeness together	The configuration emerging at the higher level is governed by a deterministic function attempting to maximize both the entropy and completeness of the chosen configuration, according to some weighted measure.	The configuration emerging at the higher level is governed by a probabilistic function attempting to maximize both the entropy and completeness of the chosen configuration, assigning probabilities according to some weighted measure.
Use completeness alone	The configuration emerging at the higher level is governed by a deterministic function attempting to maximize just the completeness of the chosen configuration.	The configuration emerging at the higher level is governed by a probabilistic function attempting to maximize just the expected completeness of the chosen configuration.
Use entropy alone	The configuration emerging at the higher level is governed by a deterministic function attempting to maximize just the entropy of the chosen configuration.	The configuration emerging at the higher level is governed by a probabilistic function attempting to maximize just the expected entropy of the chosen configuration.

9.13 Summary

I began by arguing that our ordinary notion of causal responsibility is not a purely objective notion. I argued that it rested on an objective core concept involving connections of real constraint between distinct entities, made specific by giving values to a variety of general parameters, and extended by intentional features such as the drawing of figure/ground relations. I called this core notion *causal significance* and presented a theory of it by describing the natures of the different types of causally relevant properties. I called this set of properties the *nomic content* of individuals, arguing that nomic content divided into effective and receptive properties, and I gave a theory of the relations between them. The metaphysical system elaborated in this chapter is a specific articulation of four reasonably intuitive ideas:

1. The world contains effective properties.
2. The world contains receptive properties.
3. Effective and receptive dispositions are categorically linked.
4. A causal nexus is an individual with at least two effective individuals and exactly one receptive connection.

In elaborating these ideas, I developed a view of individuals as pure property complexes by using receptivity as the causal connection and proposing that internal relations between incomplete natures would allow them to mutually complete one another. Effective properties were modeled as determinables that become determinate by conditioning one another. Conditioning is a state in which one effective individual may reduce the potentials of one or more others it is bound to by contributing to the constraints on the nexus of which they are part. Constraints come from intrinsic relations of compatibility, inclusion, and exclusion possessed by effective properties. Within the nexus, each effective property becomes part of the nature of other effective properties through their common binding to an instance of receptivity. It is by becoming part of another property's natural state through a shared receptivity that an effective property may place its constraint on other effective properties. This is one way to elaborate the intuitive notions, and I believe it is reasonable, given the determination problem and our current scientific knowledge. Yet reasonableness is one thing and fruitfulness is another. How far can this elaboration take us in understanding causation and the deep structure of the natural world?

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[1] <FN>Which notion, causal responsibility or causal significance, deserves the name *causation*? I think the ordinary language use of *causation* names causal responsibility, but I co-opt the term for the rest of this book. In most places, when I use the term *causation,* I am talking about causal significance. In the few places where I use *causation* to mean causal responsibility, I hope that the context makes the switch clear. With luck, no harmful confusion will result from these slight equivocations.

<FN>[2]And effective properties may perhaps even present constraints for the states of individuals previous to them, if the 4-D view of spacetime is correct.

<FN>[3]Although I introduce a more technical and constrained notion later, here I follow Strawson (1959) in taking a liberal attitude toward the meaning of *individual*. An individual is simply an entity that bears properties. The reason for being so liberal is to avoid heavy commitments at this early stage to what the ultimate causal ontology will be like. To quote Strawson in full:

<FN-EXT>So anything whatever can appear as a logical subject, an individual. If we define "being an individual" as "being able to appear as an individual," then anything whatever is an individual. So we have an endless variety of categories of individual other than particulars—categories indicated by such words as "quality," "property," "characteristic," "relation," "class," "kind," "sort," "species," "number," "proposition," "fact," "type," and so forth. (p. 227)

<FN>[iv] By this point scholars of causation will have realized that the theory of causal significance is going to be a theory of causal powers rather than a theory of natural law in the Dretske-Tooley-Armstrong (DTA) mode. As I continue to develop my view of the *problem* of causation, it should become clear that the central problem of causation, as I see it, is understanding the metaphysics of causal interaction: What purpose does causal interaction serve, and what are the grounds of Being that allow it to occur? I pass over the DTA model of natural laws because I believe it is not a very good model for gaining a deep understanding of causal interaction and so is not very useful for understanding the problem of causation developed in the text.</FN>

<FN>[v] One might say that the determination problem is to the theory of causal significance what the problem of causal production is to the theory of causal responsibility.</FN>

<FN>[vi] For effective properties there are the interesting questions of whether and how new effective properties can emerge from the binding of existing effective properties. Because of the possibility of emergence, straight inheritance by the higher level individuals of bound effective properties from the lower level need not always occur. These issues turn out to be very interesting, and the principles of emergence for effective properties are discussed in detail in the next chapter. </FN>

<FN>[vii] And vice versa if *R* was also part of the completion of E_{1}.</FN>

<FN> [viii] If the effective entity in the binding relation is already complete then it need not take up the nature of the incomplete receptivity, though the receptivity will still take up the effective property into its own nature as part of its own completion. </FN>

<FN>[ix] These two principles correspond closely to the idea of concrescence in process philosophy. However, "seek" is not meant literally.</FN>

<FN>[x] Here is my reasoning: The stability of particles implies that their constituent properties can hang together in a single nexus under a wide variety of circumstances. From that, we can infer that they do not constrain one another very much because, no matter what determinate values circumstances force the constituent properties to take on (within a wide range), they are able to remain together in the particle nexus. Also, the value of any property typically seems to be a function of the circumstances of the particle and not of the values of their fellow properties in the particle nexus, which implies that their fellow properties are not constraining them, at least not perceptibly.</FN>

<FN>[xi] Thanks to Anand Rangaranjan for suggesting that entropy might play a role here.</FN>