**Definitions in Douglas Kutach’s Causation and Its Basis in Fundamental Physics**

**Events**

A **possible fundamental event** *e* is a nomologically possible arena-region *R*, together with a nomologically possible arrangement of fundamental attributes throughout all of *R*.

An **actual fundamental event** *e* is an instance of a possible fundamental event in the actual arena.

A **coarse-grained event** is a set of possible fundamental events.

An **actual coarse-grained event** is a coarse-grained event one of whose members is an actual fundamental event (usually instantiated in some designated region of the arena).

An event *e′* is a **subevent** of an event *e* iff *e′*’s region is a subset of *e*’s region and the arrangement of *e′*’s fundamental attributes are included in *e*’s arrangement of fundamental attributes. An event *e* is a **superevent** of *e′* iff *e′* is a subevent of *e*.

An event is **full** iff it comprises fundamental attributes of every type throughout its entire region. (A coarse-grained event is full iff all its members are full.)

A **contextualized event** *E* is a coarse-grained event with a probability distribution assigned over all its members.

A **state** is a full event whose region is a subregion of a space-like surface.

A **global state** is a state whose region is a time slice, an inextendible space-like surface.

**Terminance and Fixing**

A fundamental event *c* **determines** (and is a **terminant** of) a fundamental event *e* iff the occurrence of *c* nomologically suffices for the occurrence of *e* (with *e*’s location relative to *c* being built into this relation).

A fundamental event *c* **fixes** a contextualized event *E* iff *c* nomologically suffices for *E*.

A fundamental event *c* **fixes a probability** *p* for a plain coarse-grained event *E* iff *c* nomologically suffices for a probability *p* for *E*.

For any possible fundamental event *f* and any two of its subevents, *c* and *e*, *e* **terminates** (is a **terminant** of) *e* iff *e* is a subevent of a member of a contextualized event that *c* fixes.

A fundamental event *c* is an **indeterminant** of a fundamental event *e* iff *c* is a terminant of *e* but not a determinant of *e*.

A fundamental event *c* **contributes** to (is a **contributor** to) a fundamental event *e* iff there exists a terminant *c′* of *e* such that *c′* with *c* excised from it is not a terminant of *e*.

A fundamental event *c* **purely contributes** to (and is a **pure contributor** to) a fundamental event *e* iff every subevent of *c* contributes to *e*.

A fundamental event *c* is a **trivial determinant** of a fundamental event *e* if the occurrence of *c* suffices (without any laws) for the occurrence of *e*.

A fundamental event *c* is a **minimal terminant** of a fundamental event *e* iff *c* terminates *e* and no proper subevent of *c* terminates *e*.

**Relation of Terminance to Space-time Structure**

An event *c* **space-like terminates** an event *e* iff (1) *c* terminates *e*, and (2) there exists a subevent *c′* of *c* and a subevent *c′′* of *e* such that (A) every point of *c′*’s region is space-like to every point of *e*’s region, and (B) the event *c′′* formed by excising *c′* from *c* (if it exists) does not terminate *c′*.

An event *c* is a **space-like pure contributor** to an event *e* iff *c* purely contributes to *e* and every point of *c*’s region is space-like to every point of *e*’s region.

A **c-path** is an everywhere differentiable path whose tangents are nowhere space-like and are well-defined and non-space-like in any mathematical limits along the path.

Points *p* and *q* are **c-connected** iff *p* = *q* or a c-path exists between *p* and *q*. Two regions are **c-connected** iff some point in one region is c-connected to some point in the other. Two events are **c-connected** iff their regions are c-connected.

A region *R* is **intermediate** between *c* and *e* iff (1) every point of *R* is c-connected between some point of *c*’s region and some point of *e*’s region, and (2) there is a connected space-like subregion *Q* of *R* such that every c-path from a point in *c*’s region to a point in *e*’s region intersects *Q*.

An event *c*’s **domain of terminance** is the union of the regions occupied by all the events *c* terminates. In paradigm fundamental theories, a point *p* is in *c*’s domain of terminance iff every inextendible c-path through *p* goes through *c*.

An event *c*’s **domain of influence** is the union of the regions occupied by events all of whose subevents *c* contributes to. In paradigm fundamental theories, a point *p* is in *c*’s domain of influence iff *c* is c-connected to *p*.

An event *c*’s **domain of contribution** is the union of the regions occupied by *c*’s pure contributors. In paradigm fundamental theories, a point *p* is in *c*’s domain of contribution iff *c* is c-connected to *p*.

**Determinism**: For any nomologically possible full event *c*, *c* determines a unique full event throughout its maximal domain of dependence. (A maximal domain of dependence for a fundamental event *c* is a region *R* generated by applying the fundamental laws to *c*, extending the arena if necessary, until *R* includes all and only those points *p* such that every inextendible c-path intersecting *p* also intersects *c*’s region.)

**Ubiquitous determination**: For any actual full event *c*, *c* determines a unique full event throughout its maximal domain of dependence.
Content Completeness: For any terminant \( c \) of any possible full event \( e \), there is a full subevent of \( c \) that terminates \( e \).

Non-spatiality: The fundamental laws disallow space-like terminance.

Continuity of Termination: For any possible fundamental event \( f \) (occupying region \( F \)) with any subevent \( e \) and any subevent \( c \) that terminates \( e \) and any subregion \( R \) of \( F \) intermediate between \( c \) and \( e \), there exists an intermediate terminant on the way from \( c \) to \( e \) occupying \( R \).

Shielding of Termination: For any possible fundamental event \( f \) with any subevent \( e \) and any subevent \( c \) that terminates \( e \), the probability any intermediate terminant \( i \) (on the way from \( c \) to \( e \)) fixes for any coarse-graining \( E \) of \( e \) is equal to the probability fixed for \( E \) by any superevents of \( i \) that are terminated by \( c \) and do not intersect \( i \)'s e-ward domain of influence.

Transitivity of Termination: For any \( e_1, e_2, \) and \( e_3 \), if \( e_1 \) terminates \( e_2 \) and \( e_2 \) terminates \( e_3 \), then \( e_1 \) terminates \( e_3 \).

Causal Directness: Any backtracking prob-influence that \( \hat{E}_1 \) exerts on \( E_3 \) (by fixing some turnaround event \( \hat{E}_2 \) that fixes a pair of probabilities for \( E_3 \)) is equal in value to the prob-influence that \( \hat{E}_1 \) exerts directly on \( E_3 \) (ignoring \( \hat{E}_2 \)).

Middle Conceptual Layer

A contrastive event is an ordered pair of contextualized events. The first member is the \textit{protrast}; the second member is the \textit{contrast}. The region where the pair agrees is said to be the contrastive event's background; the region of disagreement is its foreground.

A contrastive event \((C_1, C_2)\) fixes a contrastive event \((E_1, E_2)\) iff \(C_1\) fixes \(E_1\) and \(C_2\) fixes \(E_2\).

The maximal contrastive event fixed by \( C \) is the contrastive event consisting of whatever \( C \) fixes for the entire arena (trimmed to exclude regions where \( C \) does no fixing).

The degree to which \( E \) \textit{prob-depends} on \((C_1, C_2)\) is \( p_{\neg C_1}(E) - p_{C_2}(E) \).

A contrastive event \( C \) \textit{prob-influences} a coarse-grained event \( E \) to the degree that \( E \) prob-depends on \( C \). If the degree of prob-influence is positive, \( C \) is said to \textit{promote} \( E \). If negative, \( C \) is said to \textit{inhibit} \( E \).

A region of the arena \( R \) is \textit{intermediate} between \( c \) and \( e \) iff (1) every point of \( R \) is \texti{c}-connected between some point of \( c \)'s region and some point of \( e \)'s region, and (2) there is a connected space-like subregion \( Q \) of \( R \) such that every \( c \)-path from a point in \( c \)'s region to a point in \( e \)'s region intersects \( Q \).

A contextualized event \( \bar{I} \) is a fixed intermediate on the way from \( \bar{C} \) to \( \bar{E} \) (or \( E \)) iff the region \( R \) occupied by \( \bar{I} \) is intermediate between \( \bar{C} \) and \( \bar{E} \) (or \( E \)) and \( \bar{I} \) is the unique maximal contextualized event fixed by \( \bar{C} \) for \( R \) and \( \bar{I} \) fixes \( \bar{E} \) (or a probability for \( E \)).

Continuity of Probability-fixing: If a contextualized event \( \bar{C} \) fixes a probability \( p \) for some \( E \) and there exists some region \( R \) intermediate between \( \bar{C} \) and \( E \), then there exists a unique maximal contextualized event \( \bar{I} \) that occupies \( R \), is fixed by \( \bar{C} \), and fixes a probability \( p \) for \( E \). (This \( \bar{I} \) is a fixed intermediate on the way from \( \bar{C} \) to \( \bar{E} \).)

Shielding of Fixing: For any contextualized event \( \bar{C} \) that fixes a contextualized event \( \bar{E} \) in region \( Q \) and any contextualized event \( \bar{I} \) that is an fixed intermediate on the way from \( \bar{C} \) to \( \bar{E} \) (so that it is fixed by \( \bar{C} \) and fixes \( \bar{E} \)), then for any region \( R \) that lies entirely within \( \bar{C} \)'s domain of terminance and contains no points on a \( c \)-path going from \( \bar{I} \) to \( \bar{E} \), the contextualized event \( \bar{I} \)—defined as whatever \( \bar{C} \) fixes for \( R \cup Q \)—fixes \( \bar{E} \) (just like \( \bar{I} \) does).

Weak Transitivity of Fixing: If \( \bar{E} \) fixes a contextualized event throughout region \( R \), any event fixing \( \bar{E} \) also fixes a contextualized event throughout region \( R \).

Unidirectional Transitivity of Fixing: For any \( \bar{E}_1, \bar{E}_2, \) and \( \bar{E}_3 \), if \( \bar{E}_1 \) fixes \( \bar{E}_2 \) and \( \bar{E}_2 \) fixes \( \bar{E}_3 \) and \( \bar{E}_2 \) is intermediate between \( \bar{E}_1 \) and \( \bar{E}_3 \), then \( \bar{E}_1 \) fixes \( \bar{E}_3 \).

Strong Transitivity of Fixing: For any \( \bar{E}_1, \bar{E}_2, \) and \( \bar{E}_3 \), if \( \bar{E}_1 \) fixes \( \bar{E}_2 \) and \( \bar{E}_2 \) fixes \( \bar{E}_3 \), then \( \bar{E}_1 \) fixes \( \bar{E}_3 \).

A regular contrastivization of a coarse-grained event \( C \) is a contrastive event \((\bar{C}_1, \bar{C}_2)\) such that all three of the following conditions hold: (1) for every member of \( \bar{C}_1 \), there is a member of \( C \) agreeing with it where their regions overlap; (2) none of \( \bar{C}_2 \)'s members agrees with any of \( C \)'s members where their regions overlap; and (3) \( \bar{C}_1 \) and \( \bar{C}_2 \) agree with each other everywhere outside \( C \)'s region.

An irregular contrastivization of some coarse-grained event \( C \) is an ordered triplet \((\bar{B}, \bar{C}_1, \bar{C}_2)\) where \( \bar{B} \)'s region does not overlap with \( C_1 \) or \( C_2 \), and \( C_1 \) is identical to \( C \) (but with its location relative to \( \bar{B} \) added) and where \( C_2 \) is a coarse-grained event located in the same region as \( C_1 \) (relative to \( \bar{B} \)) but without any members that are members of \( C \).

An irregular contrastivization \((\bar{B}, \bar{C}_1, \bar{C}_2)\) prob-influences \( E \) to the degree \( p_{\bar{B}}(E|C_1) - p_{\bar{B}}(E|C_2) \).

An event \( C \) partially influences an event \( E \) iff some contrastivization (regular or irregular) of \( C \) prob-influences \( E \) to a non-zero degree.

Top Conceptual Layer

An event is a \textit{culpable cause} of \( E \) iff it successfully induces \( E \).

An actual event \( e \) (as \( C \) qua \( \hat{C} \) is \textit{culpable}_1 for an actual event \( e \) (as \( E \)) iff \( \hat{C} \) is a salient, significant promoter of \( E \).

An actual event \( e \) (as \( C \) qua \( \hat{C} \) is \textit{culpable}_2 for an actual event \( e \) (as \( E \)) iff a region \( R \) (including and surrounding \( e \)) has a contrastive effect \( \hat{E} \) imposed on it that significantly promotes \( E \). (The imposed \( \hat{E} \) is generated by taking what \( \hat{C} \) fixes for \( R \), conditionizing its protrast with a slight coarse-graining of the full fundamental event occupying \( R \), and adjusting its contrast in parallel in light of what \( C \) and other independent salient events promote for \( R \).)

An actual event \( e \) (as \( C \) qua \( \hat{C} \) is \textit{culpable}_3 for an actual event \( e \) (as \( E \)) iff it is \textit{culpable}_2 for an unfuzzled process going from \( c \) up to and including \( e \). An actual event is \textit{culpable}_4 for an actual event \( e \) (as \( E \)) iff there is a chain of culpability relations running from \( c \) to \( e \).