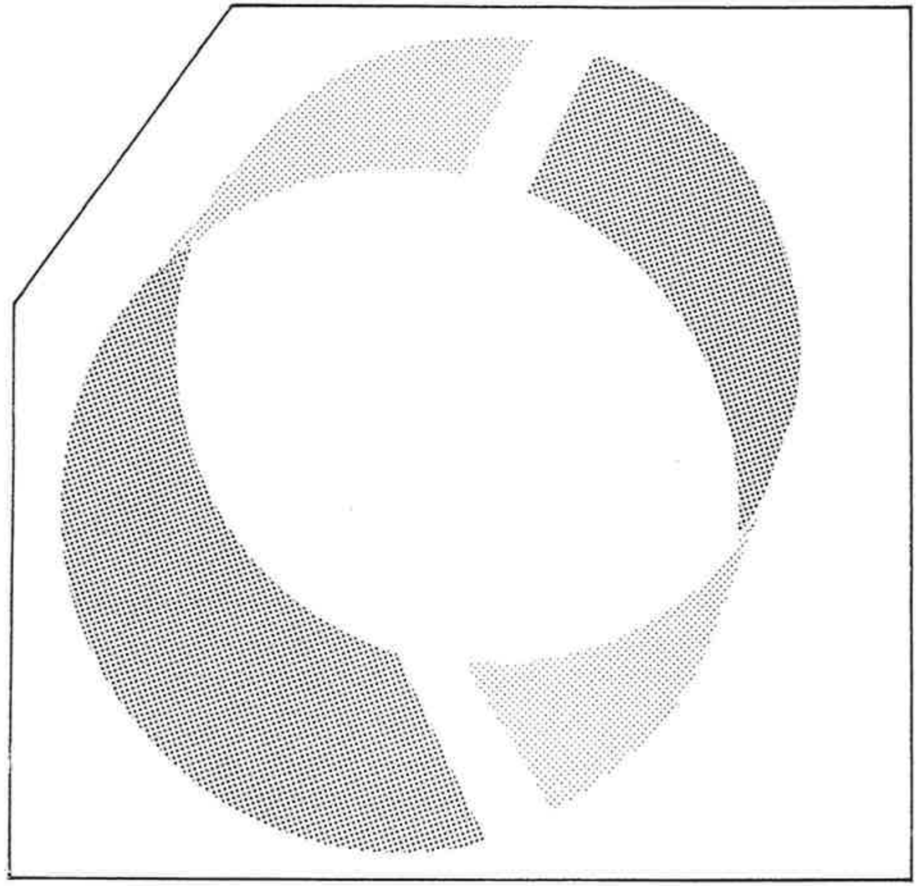
Volume 28, Number 4, 1995



COMMUNICATION & COGNITION

Communication & Cognition
Vol.28, Nr.4 (1995), pp.441-456

SOME PROBLEMS FOR KITCHER'S UNIFICATION ACCOUNT OF EXPLANATION

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1. Introduction

In Carl Hempel's deductive-nomological model of explanation, understanding an event is identified with being able to show (by means of a deductive-nomological explanation) that this event could have been expected by virtue of certain other events and certain universal laws (C. Hempel 1965, p. 337). Philip Kitcher identifies scientific understanding with unification. Unification can be provisionally characterized as systematic predictability: unifying our experiences amounts to showing that the particular events and regularities we have observed, could have been predicted by using a limited number of argument patterns over and over again. In his 1981 and 1989 Kitcher has elaborated this conception of understanding and developed a concept of explanation that matches it. In Kitcher's view, all explanations are deductive arguments, but not vice versa: only arguments that unify have explanatory power.

Kitcher regards his unification account of explanations, which is an epistemic conception of explanation, as a rival for causal approaches like Wesley Salmon's causal-mechanical model (see W. Salmon 1984). In my view, epistemic explanations are the instruments by means of which unification is achieved, while causal explanations are explanations that can provide causal understanding. Both types of explanation need to be analyzed, because understanding has at least two irreducible aspects: on the one hand there is the desire to fit all the phenomena into a unified world-picture (epistemic understanding); on the other hand there is the desire to know how things in the world work, i.e. the desire to know the mechanisms that produce the phenomena we observe (causal understanding). As a consequence of this view, the asymmetry problem disappears: epistemic explanations do not show the asymmetry which is typical of causal explanations. Criticisms of Kitcher's model which focus on the asymmetry problem (e.g. E. Barnes 1992) become pointless. I agree with Barnes that Kitcher's attempt to reduce causal asymmetries to asymmetries of unifying power is a failure, but I think there is no need for such reduction. Though the asymmetry problem disappears, I think that Kitcher's account faces a number of serious difficulties. I will discuss three of them in this article (sections 3-5). Section 2 contains a summary of Kitcher's ideas and a short presentation of the three problems to be discussed in the other sections.

2. Kitcher on scientific explanation and understanding

2.1 The central concept in Kitcher's theory of explanation and understanding is *argument pattern*. An argument pattern is a triple of (i) a sequence of schematic sentences, (ii) a set of sets of filling instructions, and (iii) a classification. A schematic sentence is an expression obtained by replacing some, but not necessarily all, of the nonlogical expressions in a sentence with dummy letters. The filling instructions are directions for replacing the dummy letters. An argument pattern contains one set of filling instructions for each entry of the sequence of schematic sentences. A classification describes the inferential characteristics of a sequence of schematic sentences. As an example, we consider the following argument pattern:

Sequence of schematic sentences:
(1) *a* is a P.
(2) All P's are bald.
(3) *a* is bald.
Filling instructions
a must be replaced with the name of an individual, P with an arbitrary predicate.
Classification
(1) and (2) are premises, (3) follows from (1) and (2) by means of universal instantiation and modus ponens.

An example of an argument fitting this pattern is:

Sequence of sentences
(1) Horace is a member of the Greenburgh School Board.
(2) All members of the Greenburgh School Board are bald.
(3) Horace is bald.
Classification
(1) and (2) are premises, (3) follows from (1) and (2) by means of universal instantiation and modus ponens.

Note that an argument is a couple of a sequence of schematic sentences and a classification. Our example is also an instantiation of the following argument pattern:

Sequence of schematic sentences:
(1) *a* is a P.
(2) All P's are Q.
(3) *a* is Q.
Filling instructions
a must be replaced with the name of an individual, P and Q with arbitrary predicates.
Classification
(1) and (2) are premises, (3) follows from (1) and (2) by means of universal instantiation and modus ponens.

For each argument, we can find many patterns of which it is an instance. If a pattern and an argument are given, we can always decide whether the argument is an instantiation of the pattern: all we have to do is check whether the filling instructions have been appropriately executed.

2.2 Kitcher uses argument patterns to distinguish explanations from non-explanatory arguments. For an individual with knowledge K, an argument A can only be an explanation if it is acceptable relative to K (i.e. if the premises of A are members of K). But not all acceptable arguments are explanations: an acceptable argument is an explanation if and only if it instantiates an argument pattern that belongs to a privileged set of argument patterns. This set of argument patterns is privileged because it has a higher unifying power with respect to K than any other conceivable set of argument patterns. The unifying power of a set of argument patterns is determined by four factors.

Firstly, the unifying power of a set of argument patterns with respect to K varies directly with the number of accepted sentences (i.e. the number of elements of K) for which we can construct an acceptable deductive argument that instantiates a pattern in the set. So ceteris paribus, the ideal set contains at least one argument pattern to account for each observed event. The second factor is paucity of patterns: the unifying power of a set of argument patterns varies conversely with the number of patterns in the set. The two first factors may be illustrated by the following argument pattern (see Kitcher 1981, p. 528):

Sequence of schematic sentences
(1) God wants it to be the case that α.
(2) What God wants to be the case is the case.
(3) It is the case that α.
Filling instructions
α may bee replaced with any accepted sentence
Classification
(3) follows from the premises (1) and (2) by instantiation and modus ponens.

The set containing only this argument pattern scores very high with respect to the two factors: the number of patterns is extremely low, and everything can be explained with this pattern. Nevertheless, the unifying power of the set is zero because of the third factor: stringency of patterns. An argument pattern is more stringent than another if there are more similarities among the instantiations of the first than among instantiations of the latter. This means that the first pattern contains less schematic letters, or that the filling instructions of the first pattern set conditions on its instantiations that are more difficult to satisfy than those set by the filling instructions of the second pattern. The pattern above has no stringency, because there are no conditions to be met when instantiating the schematic letter α. The first Horace-pattern is more stringent than the second, because it does not contain the schematic letter Q. The unifying power of a set of argument patterns varies directly with the stringency of the patterns in the set.

Finally, the unifying power of a set of argument patterns also varies directly with the degree of similarity of its members. To clarify this last factor, we consider the following argument pattern:

Sequence of schematic sentences
(1) All members of species S that belong to category XX×XY, have phenotype F_j.
(2) *a* belongs to species S and to category XX×XY.
(3) *a* has phenotype F_j.
Filling instructions
S must be replaced with the name of a species, F_j with a name of a phenotype characteristic for S, X and Y with names of genes characteristic for S. *a* must be replaced with a name of an individual of S.
Classification
(3) follows from the premises (1) and (2) by instantiation and modus ponens.

XX×XY is a type of cross: an XX×XY-individual is a descendant from one parent with genotype XX and one parent with genotype XY. An example of an argument fitting this pattern is:

Sequence of sentences
(1) Humans which belong to category II×I*i* do not suffer from the Tay-Sachs-disease.
(2) John is a human and belongs to category II×I*i*.
(3) John does not suffer from the Tay-Sachs-disease.
Classification
(3) follows from the premises (1) and (2) by instantiation and modus ponens.

The Tay-Sachs disease is also called "infantile amaurotic idiocy". In children suffering from this disease, an accumulation of complex lipids in the brains, milt and/or liver causes blindness (amaurosis) and idiocy immediately after birth; almost all children die within 10 years. The occurrence of the disease is determined by two genes, I and *i*: *ii* individuals have the disease, II and I*i* do not suffer from it. We now can explain what similarity among patterns means: in the argument pattern above we may substitute XX×XY for a different kind of cross, e.g. XX×XX or XX×YY. In this way we obtain argument patterns that are very similar to the original one but will allow us to explain other events.

In Kitcher's view, understanding is reached by constructing explanatory arguments, i.e. by constructing arguments in which parts of our knowledge are derived from other parts, and which instantiate a pattern of the privileged set. In his view, understanding amounts to showing that many events can be derived by using the same small set of stringent and similar argument patterns again and again. It is in this sense that scientific explanations unify our experiences.

2.3 I will now briefly state the three problems for Kitcher's account of explanation and understanding that will be discussed in the next sections. The first problem is that Kitcher does not require that the explanandum is subsumed under a high-level law or theory. In section 3 I will show that low-level generalisations of the form $(\forall x)(Px \supset Qx)$ are sufficient to achieve unification in Kitcher's sense. The second problem is the following: if two equally stringent argument patterns account for the same set of facts, the pattern that is most similar to other patterns in the set must be retained; the other does not belong to the set of privileged argument patterns. In section 4 I will argue that examples of such patterns can be found of which the instances are intuitively acceptable explanatory arguments. This means that Kitcher's account classifies a number of perfectly good explanations as non-explanatory arguments. The third problem (section 5) is that sometimes unification is reached by means of a "solitary" argument pattern, i.e. a pattern that can account for only one fact and is not at all similar to other patterns.

3. Understanding requires general laws and theories

3.1 To clarify the first problem, we compare two arguments. The first argument is:

Sequence of sentences
(1) All humans which belong to category $I^AI^A \times I^AI^O$ have blood group A.
(2) Mary is a human and belongs to category $I^AI^A \times I^AI^O$.
(3) Mary has blood group A.
Classification
(3) follows from the premises (1) and (2) by instantiation and modus ponens.

$I^AI^A \times I^AI^O$ is a category of cross, like $II \times Ii$ above. The phenotypes of the ABO blood group system (the blood groups A, B, AB and O) are determined by the genes I^A, I^B and I^O. This argument is similar to the argument relating to the Tay-Sachs disease used in section 2.2: it is an instance of the argument pattern given there. This pattern has many applications, is similar to other patterns, and is sufficiently stringent.

The second argument is:

Sequence of sentences
(1) For any individual *w* of any species S, and any alleles X and Y: if *w* has XY, then the probability that *w* transmits X to any one of its offspring is 0.5.
(2) For any individual *w* of any species S, and any allele X: if *w* has XX, then the probability that *w* transmits X to any one of its offspring is 1.
(3) Each human (i.e. each member of species H) possesses exactly one of the following genotypes: I^AI^A, I^AI^B, I^AI^O, I^BI^B, I^BI^O and I^OI^O.
(4) All humans with genotype I^AI^A have blood group A, all humans with genotype I^AI^B have blood group AB, all humans with genotype I^AI^O have blood group A, all humans with genotype I^BI^B have blood group B, all humans with genotype I^BI^O have blood group B, all humans with genotype I^OI^O have blood group O.

(5) $P_H(A \mid I^AI^A \times I^AI^O) = P_H(I^AI^A \mid I^AI^A \times I^AI^O) + P_H(I^AI^O \mid I^AI^A \times I^AI^O)$
(6) For all species S and all crosses of kind $XX \times XY$: $P_S(XX \mid XX \times XY) = 0.5$, $P_S(XY \mid XX \times XY) = 0.5$ and $P_S(YY \mid XX \times XY) = 0$.
(7) For all crosses of kind $XX \times XY$: $P_H(XX \mid XX \times XY) = 0.5$, $P_H(XY \mid XX \times XY) = 0.5$ and $P_H(YY \mid XX \times XY) = 0$.
(8′) $P_H(I^AI^A \mid I^AI^A \times I^AI^O) = 0.5$.
(8″) $P_H(I^AI^O \mid I^AI^A \times I^AI^O) = 0.5$
(9) $P_H(A \mid I^AI^A \times I^AI^O) = 1$, i.e. all humans which belong to category $I^AI^A \times I^AI^O$ have blood group A.
(10) Mary is a human and belongs to category $I^AI^A \times I^AI^C$.
(11) Mary has blood group A.
Classification
(1)-(4) are premises. (5) is derivable from (3) and (4) by means of probability calculus. (6) is derivable from (1) and (2) by means of probability calculus. (7) is an instantiation of (6). (8′) and (8″) are derivable from (7) by simplification and instantiation. (9) is derivable from (5), (8′) and (8″) by substitution. (10) is a premise. (11) is derivable form (9) and (10) by means of universal instantiation and modus ponens.

In Kitcher's view, unification is achieved by systematizing our knowledge by means of a few stringent patterns (in Kitcher's terminology, systematizing our knowledge means constructing arguments in which parts of our knowledge are deductively derived from other parts). If this is correct, there is no need to construct complex arguments like the second one. Simple arguments like the first one will do the job equally well, because the events we can obtain as conclusions are the same. However, the second argument provides much more insight: it shows how the explanandum could have been expected given some other facts and a general theory. The fist argument uses a very specific law statement which is not fitted into a more general law or theory. In my view, an explanation must contain a core (like sentences (9)-(11) in the second argument) and a derivation of the law statement that is used in this core from a general theory or law (as (1)-(8) in the second argument). In an explanation core, the explanandum is subsumed under a specific, low-level generalisation. In a derivation, a low-level generalisation is reduced to one or more general laws or theories (derivations thus are specific types of arguments: their conclusion is always a universally generalized conditional statement). Only arguments that contain both an explanation core and a derivation, can have explanatory power.

3.2 The fact that explanatory arguments must contain a core and a derivation does not make Kitcher's four criteria for unifying power useless: we can maintain that an argument (consisting of an explanation core and a derivation) is not a good explanation unless the pattern used in the derivation belongs to a privileged set of derivation patterns which is selected on the basis of its unifying power. Derivation patterns then are defined as argument patterns that result in a derivation if we execute the filling instructions. The derivation in the second argument above is an instance of the following pattern:

Sequence of schematic sentences
(1) For any individual *w* of any species S, and any alleles X and Y: if *w* has XY, then the probability that *w* transmits X to any one of its offspring is 0.5.
(2) For any individual *w* of any species S, and any allele X: if *w* has XX, then the probability that *w* transmits X to any one of its offspring is 1.
(3) Each individual of species S belongs to exactly one of the genotypes $G_1 \ldots G_m$.
(4) G_1-individuals have property F, G_2-individuals have property F′, etc.
(5) $P_S(F_j \mid XX \times XY) = P_S(G' \mid XX \times XY) + P_S(G'' \mid XX \times XY) + \ldots$
(6) For all species S and all crosses of kind XX×XY: $P_S(XX \mid XX \times XY)=0.5$, $P_S(XY \mid XX \times XY)=0.5$ and $P_S(YY \mid XX \times XY)=0$.
(7) For all crosses of kind XX×XY: $P_S(XX \mid XX \times XY)=0.5$, $P_S(XY \mid XX \times XY)= 0.5$ and $P_S(YY \mid XX \times XY)=0$.
(8′) $P_S(G' \mid XX \times XY)=r'$
(8″) $P_S(G'' \mid XX \times XY)=r''$
⋮
(9) $P_S(F_j \mid XX \times XY) = r'+r''+\ldots$
Filling instructions:
For (1) and (2) the set of filling instructions is empty. S must be replaced everywhere with the name of a biological species, except in (1), (2) and (6) where it is not replaced. $G_1, \ldots, G_m$ must be replaced everywhere with names of genes, F, F′ etc. everywhere with names of phenotypical traits. F_j must be replaced everywhere with one of the phenotypes for which F, F′, ... have been substituted. G′, G″, ... must be substituted everywhere for exactly those genotypes from the series $G_1, \ldots, G_m$ of which it is claimed in (4) that they result in phenotypical trait F_j. In (6) and (7) the schematic expressions XX×XY, XX, XY and YY must be retained. In the other schematic sentences, XX×XY must be replaced with a type of cross which belongs to this general kind and is possible given the genes

$G_1,\ldots,G_n$. In (7), XX, XY and YY must be replaced with genotypes from the series $G_1, \ldots, G_m$ (the genotypes we have to take are determined by the choice made for instantiating XX×XY). Finally, the schematic letters r′, r″, ... must be replaced with 0 or 0.5, so that their sum is not larger than 1.
Classification:
The classification is as in the second argument above, with two adaptations: all the equations (8′), (8″), ... follow from (7) by simplification and instantiation. (9) is the result of combining equation (5) with all the equations (8′), (8″), ...

This derivation pattern is a strong candidate for membership of the privileged set, because it is similar to other patterns (for other kinds of crosses than XX×XY) and has many applications. For instance, the law used in the Tay-Sachs example in 2.2 can be derived by means of this pattern:

Sequence of sentences:
(1) For any individual *w* of any species S, and any alleles X and Y: if *w* has XY, then the probability that *w* transmits X to any one of its offspring is 0.5.
(2) For any individual *w* of any species S, and any allele X: if *w* has XX, then the probability that *w* transmits X to any one of its offspring is 1.
(3) Each human belongs to one of the genotypes II, I*i* or *ii*.
(4) *ii* individuals suffer from the Tay-Sachs disease, II and I*i* individuals do not.
(5) $P_H(\text{T-S} \mid II \times Ii) = P_H(ii \mid II \times Ii)$.
(6) For all species S and all crosses of kind XX×XY: $P_S(XX \mid XX \times XY)$-$=0.5$, $P_S(XY \mid XX \times XY)=0.5$ and $P_S(YY \mid XX \times XY) =0$.
(7) For all crosses of kind XX×XY: $P_H(XX \mid XX \times XY)=0.5$, $P_H(XY \mid XX \times XY)=0.5$ and $P_H(YY \mid XX \times XY)=0$.
(8) $P_H(ii \mid II \times Ii)=0$
(9) $P_H(\text{T-S} \mid II \times Ii)=0$, i.e. humans which belong to category II×I*i* do not suffer from the Tay-Sachs-disease.

Classification
(1)-(4) are premises. (5) is derivable from (3) and (4) by means of probability calculus. (6) is derivable from (1) and (2) by means of probability calculus. (7) is an instantiation of (6). (8) is derivable from (7) by simplification and instantiation. (9) is derivable from (5) and (8) by substitution.

4. Two explanations for the same fact

Suppose we observe that an object *a* at time t_e has covered a distance (relative to time t_a) in the interval [q,r[metres. This fact can be explained by means of the law of falling bodies. The law of falling bodies is a couple of a definition of a model (FF_D) and an empirical claim. (FF_D) defines a set of idealized systems, viz. freely falling bodies:

(FF_D) For all bodies *x*: *x* is called a freely falling body if and only if the relation between *s* (the measure of the distance, in metres, covered by *x*) and *t* (the measure of the time, in seconds, during which *x* is falling) is given by the formula $s = 9.81 \times t^2/2$.

The empirical claim to be associated with this definition is that material bodies, if certain conditions $c_1 \ldots c_n$ are satisfied, have approximately the properties of freely falling bodies as defined in (FF_D). The conditions $c_1,\ldots,c_n$ must e.g. state that the body is not suspended in any way, that it is near the surface of the earth, and must exclude certain shapes that cause too much friction. In general, a phenomenological law consists of a definition of a set of idealized systems, like (FF_D), and the empirical claim that certain real systems, if certain conditions are satisfied, behave approximately as the idealised systems defined in the first part. The explanation core of an explanation based on the law of falling bodies would have the following form:

U: All freely falling bodies which have been falling during $[q_1,r_1[$ *sec*, have covered a distance in the interval $[q^*,r^*[$ metres.
L_E: Material bodies that satisfy the conditions $c_1, \ldots, c_n$, have a structure that is very similar to the structure of freely falling bodies.
S_1: *a* is a material body.
S_2: *a* satisfies the conditions $c_1, \ldots, c_n$.
S_3: The time during which *a* has been falling (i.e. t_e minus t_a) lies in the interval $[q_1,r_1[$ sec.

I_1: *a* has a structure which is very similar to the structure of a freely falling body.
I_2: If *a* would be a freely falling body, then *a* would have covered a distance lying in the interval $[q^*,r^*[$ metres.
E: *a* at t_e has covered a distance in the interval [q,r[metres.

$[q^*,r^*[$ must be included in or identical to [q,r[. The explanation core must be completed with a derivation of U from definition (FF_D).

The fact that *a* at time t_e has covered a distance in the interval [q,r[metres can also be explained by means of Newtonian mechanics. Newtonian mechanics is a network of theory-elements, each consisting of a definition of a theoretical model (T_D) and an empirical claim (T_E). Each T_D defines a set of idealized systems (e.g. freely falling body, harmonic oscillator), while in the associated T_E it is claimed that certain real systems, if certain conditions are satisfied, behave approximately as the idealised systems defined in T_D. The relevant theory-element contains the following definition:

(FF_{TM}) For all material objects *w*: *w* is a freely falling body if and only if
(i) $F = m.d^2x/dt^2$, and
(ii) $F = mg$,
where *x* is the position of *w* in the X-direction, *t* the time, *m* the mass of *w*, F the force exerted on *w* in the X-direction, and *g* the acceleration due to gravity (9.81 m/sec^2).

The empirical claim that accompanies (FF_{TM}) is that all unsuspended material bodies near the surface of the earth, if they satisfy certain condition of shape, behave approximately like free falling bodies. In an explanation based on this theory-element, the core would have the following form:

U: All freely falling bodies which at time t_a have a velocity in the interval $[q_1,r_1[$ metres/sec, at time t_e have covered a distance (relative to t_a) in the interval $[q^*,r^*[$ metres.
T_E: Material bodies that satisfy the conditions $c_1, \ldots, c_n$ have a behaviour that is very similar to the behaviour of freely falling bodies.
S_1: *a* is a material body.
S_2: *a* satisfies the conditions $c_1, \ldots, c_n$.
S_3: *a* at time t_a has a velocity in the interval $[q_1,r_1[$ metres/sec.
I_1: *a* has a behaviour which is very similar to the behaviour of freely falling bodies.

I_2: If *a* would be a freely falling body, then at time t_e it would have a position in the interval $[q^*,r^*[$ metres.

E: At time t_e *a* has covered a distance in the interval [q,r[metres.

This core must be completed with a derivation of U from definition (FF_{TM}).

According to Kitcher's criteria, the second pattern must be preferred: arguments instantiating the pattern of the law of falling bodies are no explanatory arguments. It is easy to see why. The facts that can be explained are the same: the conditions c_1, ..., c_n are the same in both patterns, so they have the same scope. But the Newtonian pattern has the advantage that there exist a number of other very similar patterns. While the pattern according to which sentences are derived from definition (FF_D) has no "relatives", the derivation pattern for (FF_{TM}) belongs to a family of similar patterns. Each of the patterns in the family relates to a theory-element of the Newtonian network. The structural similarities between derivations from (FF_{TM}) and derivations from definitions of other Newtonian theoretical models, result from the fact that these models have a typical structure and presuppose the same mathematical tools. The typical form of Newtonian theoretical models is:

(N) For all material objects *w*: *w* is a P if and only if
(i) $F = dp/dt$
(ii) $F = F_1 + F_2 + \ldots + F_n$,
(iii) $F_1 = \ldots, F_2 = \ldots, \ldots, F_n = \ldots$

In Newtonian derivations, we always start from the second law of motion and the force laws used to define the model. Further similarities arise because the primary mathematical tools are vector addition and differential calculus.

Though arguments based on the law of falling bodies do not classify as explanations according to Kitcher's criteria, they are intuitively acceptable. In my view, the reason for this is that they subsume the explanandum under a coexistence law. This law is complementary to Newtonian mechanics because Newtonian patterns always result in diachronical explanations: the distance covered at t_e is explained by referring to the velocity at some other time t_a. The law of falling bodies allows us to link the distance covered by a body at t_e with another characteristic of this body at the same time. A general conclusion might be that optimal unification is only reached if an event can be linked both synchronically and diachronically with other events. This explains why some arguments that in Kitcher's view do not count as explanatory, are intuitively acceptable explanations.

5. Explanation by means of solitary patterns

The last problem I want to draw attention to is that unification may be reached with solitary argument patterns, i.e. patterns that can account for only one fact and are not similar to other patterns. My example is inspired by an example of Hempel (C. Hempel 1965, p. 246). A mercury thermometer is rapidly immersed in hot water. We observe a temporary drop of the mercury column, followed by a swift rise. The core of the explanation we give is:

L: In glass tubes which are partly filled with mercury and are rapidly immersed in hot water, the mercury level first drops and then rises.

C_1: This thermometer consists of a glass tube which is partly filled with mercury.

C_2: This thermometer was rapidly immersed in hot water.

To obtain a complete explanation we must add a derivation of L from some general laws or theories. L can be derived from three general laws: the law of thermal expansion of fluids, the law of thermal expansion of solids and the law of heat conduction. The law of thermal expansion of fluids is:

$$v = v_o + v_o\beta t$$

(v: final volume; v_o: initial volume, β: coefficient of expansion of the fluid considered; t: rise (+) or fall (-) of the temperature). The law of thermal expansion of solids is:

$$l = l_o + l_o\alpha t$$

(l: final length; l_o: initial length; α: coefficient of linear expansion of the solid considered). Finally, the law of heat conduction says that the quantity of heat dQ (joules) which, in a time period dt, flows between any two plane surfaces normal to the direction of heat flow, is given by the equation

$$dQ = -KA(\delta\theta/\delta n)dt$$

(K: thermal conductivity coefficient (joule/°C.sec.m); A: area the surfaces (m^2); $\delta\theta/\delta n$: temperature gradient (°C/m)). The law "In glass tubes which are partly filled with mercury and are rapidly immersed in hot water, the mercury level first drops and then rises" can be derived from these three laws. The derivation is as follows. The law of thermal expansion of fluids gives us the equation

$$v = v_o + v_o \times 0.00018 \times t_m$$

(v: final volume of the mercury; v_o: initial volume of the mercury; 0.00018: coefficient of expansion of mercury; t_m: rise of the temperature of the mercury). On the other hand, the tube of the thermometer will expand in accordance to the following equation, which is an implementation of the law of thermal expansion of solids:

$$r = r_o + r_o \times 0.000008 \times t_g$$

(r: final radius of the tube; r_o: initial radius of the tube; 0.000008: coefficient of linear expansion of glass; t_g: rise of the temperature of the tube). Glass is a bad thermal conductor: its thermal conductivity is small. As a consequence, in a first phase, only the temperature of the tube will rise: $t_m=0$ and thus $v=v_o$. The relation between the level of the mercury and its volume is given by the geometrical formula

$$h = v/\pi r^2$$

(h: height of the mercury column; v: volume of the mercury; r: radius of the tube). From this formula and $v=v_o$ we derive that

$$h = v_o/\pi r^2$$

The initial mercury level is given by

$$h_o = v_o/\pi r_o^2.$$

Because the temperature of the tube rises ($t_g>0$), r is larger than r_o. The two last equations and $r>r_o$ imply that

$$h<h_o$$

In other words: the mercury level drops in a first phase. But as a result of heat conduction, the temperature of the mercury will start to rise after a few instants; the mercury expands (law of thermal expansion of fluids). Because the coefficient of expansion of mercury is large, the expansion will be greater that the extension of the tube. Consequently, the mercury level will rise.

The explanation core and derivation in our example show that the explanandum could have been expected given certain facts (C_1 and C_2) and three general laws. The law L must not be accepted as a brute fact once we know this explanation: it has been reduced to the three laws. The three laws may occur as premises in many derivations of specific, low-level generalisations. This is the reason why the argument has explanatory power and provides understanding. However, the pattern of derivation that was used has only one application: the derivation of L. Furthermore, there are no similar patterns that account for similar laws, because the structure of the derivation is determined by the structure of the thermometer. For instance, the structure of the thermometer entails that the heat first reaches the glass tube and then the mercury; this determines the specific way in which the three laws must be combined. The shape of the thermometer determines the geometrical formula that is used. In general, there are many explanations in which the derivation of the law is an instantiation of a solitary pattern which does not fit the Kitcherian ideal of a stringent pattern that can be used again and again and is similar to other patterns.

6. Conclusions

In this article, I have pointed at three problems for Philip Kitcher's unification account of explanation and understanding. Three general conclusions may be drawn from the examples given in the section 3-5:
(1) Explanations must contain an explanation core (in which the explanandum is subsumed under a specific, low-level generalisation) and a derivation (in which the low-level generalisation is reduced to one or more general laws or theories).
(2) Sometimes optimal unification requires two complementary explanations for the same fact: one synchronical and one diachronical explanation.
(3) There are many explanations in which the derivation of the law is an instantiation of a solitary pattern which does not fit the Kitcherian ideal of a stringent pattern that can be used again and again and is similar to other patterns.

Notes

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