Philosophy of Science // Fall 2015

Handout 8

Structure of theories: Carnap, Hempel (incomplete)

Two kinds of laws. Carnap begins by drawing a distinction between empirical theoretical laws. We understand that empirical laws are generalisations from observations. Examples may include (generalised) Boyle's law $P \times V = k \times T$ or Snell's law $\sin\theta_1 \times v_2 = \sin\theta_2 \times v_1$. Theoretical laws cannot be obtained from observations *alone*. This is because they of necessity refer to unobservables. Carnap gives an example of field equations, but a more basic example would indeed be Newton's Second Law.

Nature of observation. By 'observation' we do not mean only observations with the naked eye. We adopt the physicists' usage and also include measurement. Readings off measuring devices would also qualify as observations.

Some entities acceptable in scientific theories cannot be measured 'directly'. There must be more complex ways of detecting their influences on measuring devices. In the kinetic theory, gas temperature may be such indirect influence measurable in a normal way. Another example is electromagnetic field which, if constant, can be measured, but if changing and of small dimensions, cannot be.

Theoretical laws and explanation. Theoretical laws have the purpose of explaining empirical laws. This is achieved, in effect, by unification. Previously unrelated, apparently irrelevant empirical laws are seen, with the aid of theoretical laws, as related. The motion of molecules explains both the behaviour of gases and the behaviour of heated iron. Molecular theory belongs in the category of theoretical laws. It now connects the two empirical laws (i.e. mere empirical generalisations). The connection, Carnap thinks, is achieved by derivation: 'If there are molecules in this piece of iron, they would behave in such-and-such way.' Moreover, theoretical laws can *predict* new empirical laws. The form of prediction is the same as that of explanation, except that no empirical laws have previously been discovered.

This capacity of deriving empirical laws—whether new or previously known—is a criterion of acceptance of theoretical laws. Herein lies their link with experience, even though their content taken in isolation, so far as they refer to unobservables, might not be empirically testable.

Hempel's paradox. To give a logically coherent presentation, it is necessary to interrupt our discussion of Carnap and turn to Hempel. The question we now address is: can we define theoretical terms through observational terms? Or in other words, can we paraphrase every theoretical law in terms of some extremely complex empirical law? The pattern which the paraphrase can follow is succinctly given in the schema (4.1) in page 185. We begin with observable data, move to the level of theoretical sentences, and descend back to the level of observable predictions. So it seems that the theoretical terms are a unnecessary detour on the way to a collection of statements that can be formulated in purely observable terms.

Elimination of theoretical terms. Hempel argues that there is a possibility of a deductive elimination of theoretical terms (thanks to Craig's result). That is: if we have a theoretical law T along with a set J of rules interpreting theoretical terms of T, then their conjunction T' will have the same logical consequences as would the set of sentences of T' expressible in terms of observational vocabulary V_B alone. We skip the complicated proof of this result. However, any such elimination will result in a severe loss of simplicity.

What about the inductive import of the paraphrase? Here Hempel argues that Craig's method will not yield any predictions. The question why this exactly is so we again have to skip. But more importantly, let us see how the relation between theoretical terms and prediction works in theory T'.

The phosphorus example. Suppose we have a number of observable predicates G, T, V, E, S that all belong to the basic vocabulary V_B (see their interpretations in the article). We also have a theoretical predicate P (for 'phosphorus'). Then we have a series of statements:

$$\forall x(Px \to Gx)$$
$$\forall x(Px \to Tx)$$
$$\forall x(Px \to Vx)$$
$$\forall x(Px \to Ex)$$
$$\forall x(Px \to Sx)$$

In addition, we have another theoretical predicate I ('ignition temperature at 30°C') and the predicate F ('goes up in flames'). Only the latter is an observable predicate. So in T' we also have:

$$\forall x(Ix \to Fx)$$
$$\forall x(Px \to Ix)$$

Then we have an inductive inference, on the strength of the first group of statements, with the conclusion that a given sample is phosphorus. If this much is granted, the second group of statements yields the prediction that the given sample will go up in flames under the temperature above 30°C.

Ramsey sentence. A method alternative to Craig's is to express the interpreted theory T' is to use its Ramsey sentence. Assuming the conditionals above, the sentence will be as follows:

$$\exists\phi\exists\psi\forall x[(\phi x \to (Gx \,\&\, Tx \,\&\, Vx \,\&\, Ex \,\&\, Sx)) \,\&\, (\psi x \to Fx) \,\&\, (\phi x \to \psi x)].$$

Here P and I are replaced by ϕ and ψ.

Its advantages and disadvantages.

Meaning of theoretical statements.

Derivation of empirical laws. We return to Carnap's discussion. Kinetic theory of gases: Correspondence rules state that gas temperature corresponds to the kinetic energy of molecules. More exactly, the kinetic energy of a gas volume is proportional to the temperature of the volume.

YSB