# *The Demarcation Problem of Laws of Nature*

*Lukáš Bielik*[1]

**Abstract:** The paper focuses on the problem of identification of laws of nature and their demarcation from other kinds of regularities. The problem is approached from the viewpoint of several metaphysical, epistemological, logical and methodological criteria. Firstly, several dominant approaches to the problem are introduced. Secondly, the logical and semantic explicatory framework – Transparent Intensional Logic – is presented for the sake of clarification of logical forms of sentences that are supposed to express the laws of nature. Finally, a complementary strategy to the demarcation problem is proposed, including reconsideration of relevant metaphysical, epistemological, logical and methodological requirements and principles behind the former conceptions.

**Keywords:** laws of nature, causality, Transparent Intensional Logic, universals, demarcation.

The belief that there is a difference between non-lawful contingent regularities and objective lawful patterns of nature is prevalent in scientific community as well as among the laymen. We do not seem to consider, for example, mortal consequences of car accidents as a matter of irregular behavior, but as something we could take as a natural characteristic of some processes we are acquainted with. On the other hand, we admit that the fact you arrived late at work may bring about

1 I wish to express my thanks to Marie Duží, Pavel Materna, Eugen Zeleňák and Marián Zouhar for several comments and suggestions to the earlier version of the paper and to Pavel Materna for sending me the manuscript of his *Ordinary Modalities*.

 

that you loose your job or that your boss pardons you or ignores you. We accept that some regularities we are participating on, e.g., keeping the job, is something that can be sometimes changed, interrupted or influenced with or without our intervention. Nevertheless there seems to be a multi-faceted distinguishing line between laws of nature and non-lawful regularities that still attracts the attention of philosophers of science. Henceforth, I call this the demarcation problem of laws of nature (or, for short, the demarcation problem).

In this paper I am going to reconsider the status of this problem with respect to some metaphysical, epistemological, logical and methodological criteria. Firstly, I will formulate several dominant approaches to the issue together with an explicatory sketch of their theoretical principles and presuppositions. Secondly, I am going to articulate the logical and semantic explicatory framework, Transparent Intensional Logic. This system is helpful in expressing, characterizing, and distinguishing logical forms of law-like statements from the other ones. Finally, I propose a complementary strategy to handle with the demarcation problem; the strategy consists in reconsidering the relevant metaphysical, epistemological, logical as well as methodological requirements and principles behind the above mentioned dominant approaches.

First of all, we should delineate different meanings with which the expression (or, better, the same graphical pattern of different expressions) "law of nature" is endowed. Mittelstaedt and Weingartner in their *Laws of Nature* mention five different meanings of this term (2005, 7n.). There seems to be at least these prevalent usages:

The phrase "law of nature" may be used in the following different meanings:

a) an inventor's or discoverer's idea or thought;
b) something inherent to things, which governs their behavior;
c) law statement formulated in some scientific theory;
d) some objective but ideal pattern of things with respect to which a law statement expresses only an approximation;
e) an ideal conceptual entity.

Now, someone could propose to reformulate the demarcation problem as follows: What makes a statement a law statement (or law-like)?

Or, what criteria are there for accepting one statement and not another one as law-like? Of course, someone could contest that we should prefer to pose the problem in less neutral clothes; we might ask, for example, how we come to identification of this or that objective ideal pattern of things' behavior, or under which circumstances are the laws discovered? These formulations might indicate that we *take it for granted* that laws of nature are objective ideal patterns, or something inherent to things, or an inventor's idea, etc. On the other hand, the position which aims at distinguishing criteria between law-like and non-law-like statements could sound better because it is open to the question of further characterization of laws.

It should be clear that none of these options is equivalent to the demarcation problem, although one of them is very close to it (see below). The demarcation problem can thus be articulated in an extended form as follows:

(DP) What are the distinguishing (metaphysical, epistemological, logical, and methodological) features of laws of nature? Or, which (metaphysical, epistemological, logical, and methodological) attributes make something a law of nature?

Thus, we accept the belief that the question of what criteria need to be fulfilled for a statement to be law-like seems to presuppose the answer to the question of what it is to be a law of nature. It seems reasonable to maintain that statements may be called law-like if they express (more or less precisely) laws of nature. If such statements belong to the framework of some scientific theory, they are usually called scientific laws.[2] We are probably familiar with a bunch of scientific laws from distinct scientific areas, e.g., with laws such as Newton's laws of motion, Mendel's laws of inheritance, Ohm's law, Laws of Thermodynamics, and many others. We, as well as scientists, may agree that these statements express relevant (approximations of) laws of nature. Nevertheless, we both may felt worried when asked to provide distinguishing criteria for identification of something as a law of nature.

[2] Of course, I am not excluding social or economical laws as candidates of law-like statements.

Now we are going to introduce some of the main strategies which try to give a satisfactory account for this problem.

## 1 Main Theoretical Conceptions

Several theoretical conceptions were developed to deal with the question of identification of laws of nature and their systematic separation from other regular patterns of behavior in the universe. In what follows, I am not going to provide a systematic review of all main approaches. Rather, I select some of the recognized positions and try to extract and examine, from different philosophical viewpoints, some of the basic principles they rely on.

Our analytical journey starts with the Regularity conception of laws of nature, which may be traced back to Hume, at least. Then given some constraints and supplementations we arrive at the framework of a more complex position, which Psillos calls the Web-of-laws conception (see his 2002, 148). Finally, we explore the principles and assumptions of the Universals conception of laws of nature as presented and advocated in works of D.M. Armstrong (1983), F.I. Dretske (1998) and M. Tooley (1987).

### 1.1 The Regularity Conception of Laws

I dare to say that the most natural way for a layman to identify the laws of nature is to discover regular patterns of the material objects behavior.

Tracing back the roots of this conception, there seems to be a demonstrable lineage going at least to David Hume's *Treatise* and *Enquiry* (see 1960, 2007). Though Hume's considerations focus, in this context, primarily on the identification of causal relations in our experience, they are nevertheless closely related to the identification problem of laws of nature. For if Hume characterizes a causal relation between two objects as a relation of *contiguity*, *temporal succession* and *constant conjunction* (see 1960, 75 – 88), and later on gives several instrumental rules for identification of cause and effect, where he, besides, declares that „the same cause always produces the same effect and the same effect never arises but from the same cause", then it is natural to take, at least, the laws of nature that express causal relations among spatio-temporal entities as tied with his causal reflections.[3]

It is beyond the aim of the paper to trace the historical reconstruction of this view. I postpone the dispute for other occasions.

Now let me borrow from Psillos (2002, 137) three simple formulations that characterize Hume's conception of causality and its relation to that of the Regularity view of laws.[4] Consider the statements (1) and (2) as the core idea of the regularity conception of causality:

(1) Causation is a species of regularity.
(2) The species of regularities that causation reduces to are laws of nature.

Now, statement (3) seems to be a plain and still inexplicative formulation of regularity conception of laws:

(3) Laws of nature are regularities.

The last sentence, however, is simply unhelpful when we want to determine, which regularity is (connected with) the law of nature and which one is not. Different strategies were developed to specify the relevant kind of regularity as law-like. One of them is going to join this issue to the definition of law-like statements. As Molnar maintains in (1969, 79), a statement *p* expresses a law of nature if and only if:

(a) *p* is universally quantified; and
(b) *p* is omnitemporally and omnispatially true; and
(c) *p* is contingent; and

3 Cf. Hume (1960, 173n.).

4 I am aware of the possible objection pointing to Hume's so-called second definition of cause from his *Enquiry*; he says, of causal relation between cause and effect, that „if the first object had not been, the second never had existed" (2007, 56). This seems to open a question whether we are really justified to ascribe the narrowly conceived regularity view of causation (and laws of nature) to Hume. I, as was earlier said, leave a bunch of interpretation problems for other occasions.

(d) $p$ contains only nonlocal empirical predicates, apart from logical connectives and quantifiers.[5]

It is not difficult to find counterexamples to condition (d) as long as we consider Kepler's laws as (descriptive, non-causal) laws of nature. The condition (a) and (c) is typical also of accidental, non-law-like regularities, e.g., all (my/your/our) working weeks start on Mondays. Unfortunately, the troubles springing from such a theoretical position seem to go deeper than was perhaps originally supposed.

Going back to the first approximation statement (statement (3)) and using formal tools of First order logic, the usual candidate for a logical representation of some simple regularity structure of laws of nature may be put as follows:

(RLS) $(\forall x)\ (\phi(x) \rightarrow \psi(x))$.

The formula represents any law-like statement with predicate variables $\phi$ and $\psi$ for intended properties of objects x. We thus say that for every object x it holds that if it has a property $\phi$, then it has the property $\psi$. So we may, for example, represent and rewrite the First Kepler law in the form: For every object it holds that if that object is a planet of the Solar system, then it revolves in an elliptical orbit with the Sun at one of the focuses.

From the perspective of First order logic, this logical form is unfortunately shared also by non-law-like statements that express some kind of regularity processes as well. Moreover, we know from the definition of implication in classical logical systems (e.g., First Order Logic) that every proposition, which has the form $p \rightarrow q$, is true if and only if its antecedent $p$ is false or the consequent $q$ is true. Thus in the case that the antecedent proposition is false, the whole implication is true. But our pre-theoretical intuitions about the truthfulness of law-like statements seem to contain more than this.[6]

5 For clarity, the nonlocal empirical predicates are such predicates that are not relativized to locations or places.

6 For we usually suppose that the antecedent of conditional law-like statement is true, because if this is so, the consequent must be true, if we hold the implication statement as a whole to be true.

One possible correction could be added, according to A.J. Ayer, if we would take the laws of nature to have the logical form of (RLS*):

(RLS*)$(\exists x)\ \phi(x) \wedge (\forall x)\ (\phi(x) \rightarrow \psi(x))$.

But Ayer immediately warns us that such a step is stronger than the warrants we usually meet in scientific practice (Ayer 1998, 817). Consider Newton's First law of motion as an illustration. This law statement says that for any body it holds that if there is a body on which no forces are acting it will continue at rest or in uniform motion along a straight line. However, this law seems to say nothing about the existence of such an entity. In fact, what we actually know is that there is no such entity. If we take this statement as an expression of a law of nature and accept that the statement does not state any existential commitment, then we probably have to deny the proposed correction.

I will return to this problem in section 3. For now let us stop shortly and look once more at the characterizations of this approach. What is the regularity attribute a quality of?

Discussions regarding the weaknesses of the Regularity conception of laws are usually shrouded in ambiguities. For when we say that the laws of nature have the form "all $\phi$'s are $\psi$'s", we may mean more or less different things. Some of them may be:

- i) All observed $\phi$'s have been $\psi$'s.
- ii) All experimentally tested $\phi$'s have been $\psi$'s.
- iii) All observed (experimentally tested) as well as unobserved (experimentally not tested) $\phi$'s are $\psi$'s.
- iv) There is something behind what we observe that makes all $\phi$'s to be $\psi$'s.
- v) It is a consequence of a theory T (or a result of calculation), that all $\phi$'s are $\psi$'s.
- vi) It is an axiom of a theory T, that all $\phi$'s are $\psi$'s.

What seems to underlie these specifications of regularity is a class of several different contexts in which the regularity attribute is functioning in a *proprio modo*. Thus we may argue that the sentence i) expresses *observational* regularity; the sentence ii) explicitly states *experimental* regularity; the statements iii) and iv) may represent *hypothetical* regularity as well as some *metaphysical* principle of regularity or *by-product* regularity which may be interconnected with *causal notions*; v) seems to point to *consequentional* or *theoretically implied* regularity; and vi) stands, reversely, as a *theoretically fundamental* or *presupposed* regularity.

These different contexts in which the regularity attribute is used require possibly distinct criteria of appraisal. For when we suggest that all experimental results achieved under various conditions display such and such regularity, we have probably undergone some theoretical and practical preparations that may affect the whole test performance and identification of experimental results. Those tools, on the other hand, may absent in the case of observation of regular behavior among the familiar objects in the world. Still, things are different when we take a hypothesis that certain regularity plays such and such a role in a given theoretical framework.

The idea that the law statements express some kind of regularity behavior and that the regularity is a typical attribute of laws of nature, is really not so trifling. To reconsider the Regularity conception appropriately, we have to distinguish carefully contexts of regularity ascription. Let's analyze them.

First of all, take into account a context in which we interpret the regularity of laws as observational regularity. When asked to provide a criterion of differentiation between accidental non-law-like regularities and those of laws of nature, we may resort to *observation* as the only source of adjudication. In that case Hume's skeptical considerations arise. When observing two distinct but spatio-temporally close objects, we find out just that they are spatially contiguous, temporally successive and occur, at most, in constant conjunction. However, these features are revealed also in the cases of accidental non-law-like regularities. So, identifying laws and distinguishing them from accidental regularities only due to observation, seems to be a pretty weak *epistemological criterion*.

Now, let us examine the prospects of the so-called experimental regularity. The intuition seems to be clear enough. There is a distinction between those cases that demonstrate some regular pattern without our possible intervention and those instances that remain *invariant* across various relevant changes of conditions. I rely here on Woodward's concepts of *intervention* and *invariance* as defined in his seminal work (2003, 94 – 107; 239 – 314). In a simple form, the idea is expressed as follows: Given that X and Y are variables of any magnitudes,

> *an intervention* on X with respect to Y changes the value of X in such a way, that if any change occurs in Y, it occurs only as a result of the change in the value of X and not from some other source (2003, 14);

and further on:

> A generalization *G* … is *invariant* if *G* would continue to hold under some intervention that changes the value of X in such a way that, according to *G*, the value of Y would change – "continue to hold" in the sense that *G* correctly describes how the value of Y would change under this intervention. (2003, 15)[7]

The criteria of appraisal consisting in experimental testing differ from those of observing. Thus, we have a possible *methodological* key for distinguishing the regularities that hold invariantly across certain relevant interventions and those that do not. This *experimental* or, in principle, *manipulationistic* approach seems to eliminate, as candidates for laws of nature, those observed regularities that hold only coincidentally and exhibit constant conjunction merely on phenomenological level under special circumstances. Such an experimental regularity may indicate an inner *causal* mechanism behind some observable machinery. The regularity attribute such conceived may be reasonably taken as one of important features of laws of nature, though it is not the only one.

Still, the talk of regularity may overcome the sense in which this attribute is connected with observed or experimentally tested instances. In that case we may, for example, take a particular kind of regularity (e.g., All Fs are Gs) as a *hypothesis* or a *metaphysical principle* that may be supported by observed and tested examples but is not, nevertheless, exhausted by positively verified instances. What is presupposed here is a kind of regularity and it is possible to set forth various methodological reasons to support it. Thus, observation and

7 Nevertheless, my considerations do not correspond to Woodward's characterization of laws, since his conception admits that there are generalizations that remain invariant across relevant interventions without being laws.

tests can be just one kind of warranty; explanatory and predictive successes are, possibly, the other one.

Both kinds of context mentioned above are tied, as we have seen, to the theory apparatus. One possible theoretical position uses axioms of a theory to establish some kind of regularity; several reasons can be brought forward for doing this. We deal with this option in the next subsection. On the other hand, another possible view on regularity in some theoretical frameworks may be based on derivation from other assumptions (which can legitimately express other regularities). Since these assumptions are already warranted, their deductive consequences – be they representatives of regularities – do not need additional justification. This possibility indicates that some law-like statements may express regularities given special theoretical assumptions, axioms or postulates.

I believe that at least those contexts in which it is possible to identify some kind of regularity as something that can be taken as a characteristic feature either of some epistemic or methodological, or metaphysical conditions, may prevent us from a somewhat hasty conclusion that the regularity attribute predicated of whatever belongs to philosophical garbage.

### 1.2 The Web-of-Laws Conception

As it will be seen in section 3, I consider the regularity of some kinds of processes as an important, though incidental, feature of laws. This feature may be properly explicated in a sufficiently expressive logical and semantic framework; I shortly introduce such a framework in section 2.

Now I am going to pay attention to our second position whose founding fathers are probably F.P. Ramsey and D. Lewis.[8] Their view puts the problem of laws of nature into connection with broader scientific area – scientific theories. But still, laws of nature are represented

[8] See Lewis (1973) and Ramsey (1978). Sometimes signs of these conceptions are traced back to Mill and his (1886); at least Psillos thinks this is so in his (2002), for example.

as universally quantified statements, therefore expressions of regularities of a kind.

In search for a distinction between the statements expressing laws of nature and those of accidentally true generalizations (besides the question of facts), Ramsey rejects the possibility that the real demarcation criterion consists in our different epistemic attitudes toward these classes of propositions: "We have seen that it is not their spatio-temporal indifference, not that they are believed" (Ramsey 1978, 131). Ramsey refutes that a constitutive feature of the distinction consists in a privileged cognitive attitude towards propositions but he, nevertheless, gives this privilege to the whole theoretical system. As he continues:

> … even if we knew everything, we should still want to systematize our knowledge as a deductive system, and the general axioms in that system would be the fundamental laws of nature. (1978, 131)

Despite the fact that Ramsey abandoned this position in his later writings, some philosophers have found it attractive. Lewis advocates this deductive-systematic strategy (the Web-of-laws conception) and says, in addition, that the simplicity and strength of true deductive systems, though sometimes in tension, are virtues that determine the relevant choice of axioms and law-like assumptions (cf. Lewis 1973, 73).

Slightly modified, the principle of the Web-of-laws conception can be formulated as follows:

(WL) The regularity expressed by "All Fs are Gs" is a law of nature if and only if the statement "All Fs are Gs" is an empirical (extralogical) axiom or postulate of the ideally organized deductive system with respect to simplicity and strength of the theory.

Firstly, look at the apparent benefits of this conception. As we have seen in subsection 1.1, one kind of context in which regularity may occur is the body of a scientific theory. One of the constitutive reasons to incorporate a proposition which is a representative candidate for a law of nature into theoretical framework is, according to Ramsey and Lewis, the potential of an ideally simple as well as strong systematization of our knowledge as a deductively closed body. The idea that law statements need to function in a whole web of theoretical assumptions seems to be very close to scientific practice. Likewise, the question of identification and demarcation of laws from non-laws is probably tractable only against broader theoretical elements. We could therefore get a feeling that this strategy effectively solves our issues.

Unfortunately, things are much more complicated. For the Web-of-laws conception does not distinguish satisfactorily the question of constitutive features of laws from that of their recognition and identification by us. We evidently admit that there are plenty of laws that have not yet been deductively systematized and our actual knowledge of some of them seems to be just a happy story in our cognitive enterprise.

Furthermore, the declared virtues of theoretical simplicity and strength seem to be critically vague in the context of appropriate axioms selection. On the other hand, as we already suggested, the choice of extra-logical axioms and postulates of a given theory is in general determined by many other methodological, epistemological or metaphysical reasons, one of them, perhaps, being the scope of their prediction and explanatory power, the other one being relevant empirical support, etc. Some systematizations may have magnificent explanatory power as opposed to their theoretical complexity, others may stick out due to their simplicity but be, at the same time, weakly testable.

Of course, every systemization has its own borders of applicability. For the concepts of Newton's mechanics apparently identify other objects (individuals, properties, relations, etc.) than those of quantum mechanics. Thus, several different theoretical systems may exist side by side in a given scientific area; the criterion of the best deductive systemization is insufficient for demarcation of those theoretical postulates that express laws of nature.

### 1.3 Universals and the Laws of Nature

The third approach to the identification and demarcation problem of laws of nature to be analyzed here is that of Armstrong (1983), Dretske (1998) and Tooley (1987); it is known also as the Universals theory of laws. According to their conception, the laws of nature are supposed to be *relations of contingent necessitation among universals* rather than some kind of regularity. Before sketching general principles of the conception let us have a look at some of the weaknesses of the regularity conception(s) they have pointed to.

Firstly, as mentioned already in subsection 1.1, if we take a law of nature to have the logical form of the formula (RLS), then the law statement is true, due to the definition of material implication, provided the antecedent of implication is false.[9] The law statement "All metals conduct electricity" is true even if there is no metal in the universe. Although this drawback seems serious – and we have seen that the additional proposal to consider laws as having the form of (RLS*) is itself problematic – we should not overlook the level on which the offensive is led against the regularity conception. I present my view on it in section 3.

Secondly, there are so-called uninstantiated or noninstantial laws. The law statements that express them are true not only when their antecedent is false, but we do (theoretically) know that there is nothing (in our universe) that could fulfill the conditions or have the qualities expressed in the antecedent of such an implication.[10] As a handy example consider again Newton's First Law of Motion. There are apparently no things in the universe that are not subjected to any external physical force; thus, the antecedent of Newton's First Law is in fact false.

Thirdly, a lot of scientific laws that are taken to express laws of nature have a functional character where the elements of functions represent (dependent or independent) variables. Of course, there are such values of variables of this functional relation that are never (in our world) realized or for which this relation does not hold anymore. As the universals theorists proclaim, if the regularity theory of laws is correct, the question stands: "How is it possible to explain that just

9 This objection is discussed, e.g., in Ayer (1998, 816n.) or Armstrong (1983, 19n.).

10 Here we find also differences among Armstrong, Tooley and Dretske regarding the question of uninstantiated laws. While Armstrong believes there are no uninstantiated genuine laws of nature, Tooley holds the opposite view. See Tooley (1987, 38).

this one value interval (of a magnitude) is suitable for the function (due to regularity)?"

Fourthly, as Dretske puts it in his (1998, 827n.), the [expressions of] laws of nature cannot be taken as being about the extensions of predicate [expressions], which seem to be the proper objects of regularity theory.[11] We may only agree on this point. Nevertheless, the objection does not disqualify every possible position of the regularity stance and, therefore, the idea of regularity can be easily modified and imported into some version(s) of the regularity theory.

Having these difficulties in mind, Armstrong, Dretske and Tooley (A-D-T) base their approach to the identification and demarcation problem on their (mildly different) theories of universals. They take universals as properties and relations of material objects that are inherent in, and dependent just on, them.[12] So, at least for Armstrong, universals of (empirical) particulars are nothing but abstractions from all the states of affairs in which a particular has the property (Armstrong 1983, 84).

It is my aim neither to discuss the details of their approach nor to analyze what I consider to be the defects of their universals theories. I just take their idea that the laws of nature are identified as relations of contingent necessitation among universals. According to them, law-like relations hold not of logical necessity but of some physical necessity. The A-D-T view is such that to be a law of nature means there is a contingent relation "N" among the universals, for example "F" and "G". If it holds that N(F,G), which is of a contingent matter, then this „state of affairs" *entails* that all Fs are Gs. We could express it more clearly: If there is a relation N, which holds for properties F and G, then it logically follows that all instances having the property F have the property G.

This simple conjecture brings a lot of difficulties. Let us have a look at several of them. Firstly, it is not clear how to identify empirical

11 Precisely, Dretske says: "It is not that when we have a law, 'All F's are G's', we can alter its truth value by substituting a coextensive predicate for 'F' or 'G'" (Dretske 1998, 828).

12 Especially, Armstrong rejects the objectivity of properties and relations that are not instantiated in material objects. Tooley's views differ here.

relations between empirical properties without identifying the individuals (particulars) that exemplify them.[13] I admit one may *postulate* such a relation. Nevertheless, I suppose that we should provide some empirical grounds for such an assumption; this seems to be lacking in the A-D-T conception. Secondly, the acceptation of only those properties that have been or will be exemplified in the history of universe misses the point of scientific theories; scientific theories are, so to speak, not only about the things allowed by laws of nature but also about what is forbidden "by nature" (i.e., what is supposed to be unrealized in our world at every time). Thirdly, the relation of contingent necessitation is assumed to be a primitive one in the A-D-T theory. However, it is this relation that is in need of explanation. For, what does it mean for a relation (of properties) to be physically necessary but logically contingent? A-D-T provide us with no clear answer. I dare to claim that there is no easy way out without an explicatory framework in which it is possible to draw distinctions between logical and other kinds of modalities. Finally, we can hardly say that a statement of the form N(F,G) entails a statement of the form (RLS), unless it is not clearly stated what is this relation of contingent necessitation and how the latter statement is logically "contained" in the former one.

Thus, the first step of departure of A-D-T from the wholly extensional framework of regularity theories is something we can gladly embrace. Unfortunately, the explicatory tools of universals theorists are themselves far from being sufficient.

In what follows, I briefly unroll the explicatory tools of a logical system within which it is possible to make clear distinctions with regard to different kinds of statements (sentences) and propositions, respectively.

## 2 The Framework of Transparent Intensional Logic

Transparent intensional logic (shortly "TIL") is a hyperintensional logical system, founded by Czech logician Pavel Tichý (see, in particu-

[13] Psillos calls this objection the identification problem and ascribes it to van Fraassen.

lar, his 1988) and elaborated further by Marie Duží, Pavel Materna, Bjørn Jespersen, Pavel Cmorej, Jiří Raclavský, etc.[14] TIL is based on a version of ramified hierarchy of types and a procedural interpretation of Lambda calculus' terms that are supplemented by other procedures in TIL. The meaning of (logical as well as extra-logical) expressions is taken as irreducible to set-theoretical (intensional or extensional) entities. Meanings are construed as structured objectual abstract procedures called constructions that identify (construct (dependently on a valuation)) intensional or extensional entities explicated as (partial) functions or other constructions. More precisely, an expression expresses (or represents) a construction that identifies (or constructs, dependently on valuation) an intension or an extension or some other construction. We say in TIL that a constructed object is what a given expression denotes (independently on the state of affairs). I just provide a sketch of the principles and definitions of TIL. The reader is invited to consult the cited publications.[15]

Let us say a word or two about the semantic level in which an expression denotes something. The underlying idea is simple. Using natural language expressions, we certainly want to identify different types of objects. Thus, we speak about individuals to which we ascribe properties as well as relations. So the choice of individuals as an atomic type of objects is obvious. Of course, to communicate means to convey some information or other to audience. To be able to do that, we need to be able to distinguish the truth and the falsity of sentences; so, the truth values are needed as well. Similarly, almost every empirical state of affairs tends to change across time. Such a change can be relativized, for example, to times that can be represented by real numbers. However, the temporal variability is just one kind of change. The other one concerns the possibility of different circumstances (at the same time); this is generally called modal variability and is covered by the concept of possible worlds.

It is therefore convenient to take as an epistemic base the set of the following pre-theoretical objects represented by different Greek let-

14 See, for example, Duží – Jespersen – Materna (2010), Materna (1998), Cmorej (2001), Raclavský (2009).

15 See the note 14.

ters: the set of individuals – ι, the set of truth values – ο, the set of times/real numbers – τ, and the set of possible worlds (logical space) – ω. Other types of objects may be formed from such a base, e.g., properties (of individuals), relations (between individuals), propositions, individual roles, magnitudes, as well as classes of objects (of different types), classes of propositions and so on.

One and the same object, e.g., a property or a truth value, can be semantically identified in many different ways; these ways differ not only in their meaningful constituents, but also in manners in which those constituents are composed together. TIL calls such structured meaningful entities *constructions.* There are two kinds of atomic constructions, i.e., constructions that do not consist of any other constituent but themselves.

First of all, infinitely many variables for every type of object are indispensable. So *variables* are the simplest constructions that construct objects of a given type dependently on a valuation function. A valuation function assigns to the individual variable $x_i$ the *i*-th individual from a sequence of objects of given type. (Do not confuse variables that are extralinguistic objects (constructions) with expressions for variables that are linguistic objects.) The second kind of atomic constructions is called *trivialization*. This strangely-looking, yet theoretically indispensable, kind of construction serves to identify conceptually objects of any type, even a construction. If X is any object, then the trivialization of X (in symbols $^0$X) directly (conceptually) identifies this object without mediation of any other construction. Trivialization is something like a conceptual (or constructional) constant. These two kinds of constructions occur in more complex constructions that are objectual counterparts of application and λ-abstraction in Lambda calculus.[16] In TIL, the former is *composition* and the latter *closure*. Composition $[XX_1 \ldots X_m]$ is a procedure of applying a function *f* constructed by the first constituent *X* on the tuple of arguments *a* constructed by the constituents $X_1$, …, $X_m$. It constructs (dependently on valuation) the value of *f* at *a* provided *f* is defined for *a*, otherwise the composition does not (*v*-)construct anything, it is *v*-improper. Finally, closure is

16 For simplicity, I omit, without a loss of expressive power, *execution* and *double execution* that are other kinds of construction.

a kind of construction that constructs a function *f* in the ordinary manner of lambda calculi.

It should be clear that constructions may construct not only first order objects, but also other constructions. Preventing the vicious circle, the principle of hierarchy of types must be applied. It means that every construction constructs an object of a lower type.

Given this sketchy exposition, I simply reproduce the general definition of ramified hierarchy of types adopted in a slightly modified version from Materna (1998):

*Definition 1 (Ramified hierarchy of types)*

Let B be a collection of disjoint non-empty sets {ι, ο, τ, ω}.

*Types of order 1*

1. Each member of B is *a type of order 1 over B*.
2. Let $\alpha$, $\beta_1$, …, $\beta_n$ be *types of order 1 over B*. Then the set of all partial functions $(\alpha\beta_1\ldots\beta_n)$ from $\beta_1\times\ldots\times\beta_n$-objects to $\alpha$-objects is *a type of order 1 over B.*
3. *A type of order 1 over B* is only what satisfies conditions 1 and 2.

*Constructions of order n*

Let $\alpha$ be a type of order n.

4. Any variable that *v*-constructs $\alpha$-objects is *a construction of order n.*
5. Let X be an $\alpha$-object. Then $^0X$ is *a construction of order n.*
6. Let X, $X_1$, …, $X_m$ be constructions of order *n*. Then $[XX_1\ldots X_m]$ is *a construction of order n.*
7. Let $x_1$, …, $x_m$, X be constructions of order *n*. Then $[\lambda x_1\ldots x_m X]$ is *a construction of order n.*

*Types of order n+1*

Let $*_n$ be the collection of all *constructions of order n*.

1. $*_n$ and every type of order *n* is *a type of order n+1.*
2. Let $\alpha$, $\beta_1$, …, $\beta_m$ be *types of order n+1.* Then the collection of partial functions $(\alpha\beta_1\ldots\beta_n)$ is *a type of order n+1.*
3. *A type of order n+1* is only that determined by clauses 8 and 9.

Having sketched the basic framework of TIL, we should have a look at the distinctions we can draw using its fine-grained explicatory tools.

First, the most important distinction is between expressions that denote intensions and those denoting extensions. If $\alpha$ is any type of object, $((\alpha\tau)\omega)$ is called intension; it is a function from possible worlds to chronologies (sequences of times) of $\alpha$-objects. We abbreviate the notation of intensions as $\alpha_{\tau\omega}$, for any type $\alpha$. Extensions are objects of any type $\alpha$ that are not functions with the domain of possible worlds.

Some examples might be helpful. If $\alpha$ is an object of type $(o\iota)$, it is a class of individuals; if $\alpha$ is an object of type $(o\tau)$, it is a class of (real) numbers or that of times. Neither type is an intension. On the other hand, types $(o\iota)_{\tau\omega}$, $(o\tau)_{\tau\omega}$ are types of intensions: the former one is the type of a property of individuals, the latter one that of a property of numbers.

Concerning sentences, there is a class of those that denote extensions, i.e., the truth values, as well as a class of those that denote intensions, i.e., *propositions* (functions from possible worlds to chronologies of truth values (type $o_{\tau\omega}$)). These are sentences whose truth-value depends on a given state of affairs. (For the sake of simplicity, I ignore here the class of sentences that are not defined for given possible worlds and times.) So, the sentence "2 + sin(0) = 2" denotes a truth value while the sentence "Arvo Pärt is a composer" denotes a proposition.

Mathematical and logical sentences, unlike empirical ones, denote, from the viewpoint of TIL, truth values, the True or the False. It means that their truth value does not depend on possible worlds and times. The partiality problem aside, their truth value is constant for every possible world and every time. This can be represented as follows: Let $p$ be of a type $o_{\tau\omega}$, $w$ be a variable of type $\omega$ and $t$ be a variable of type $\tau$; the class of mathematical and logical propositions that are true in all possible worlds and at all times is constructed by:

(LN) $\lambda p[{}^0\forall.\lambda w[{}^0\forall.\lambda t[p_{wt}]]]$.

We have said that the types of objects defined on an ordered pair <possible world, time> are called intensions. So, logical and mathematical sentences denote extensions or a special kind of intensions –

the trivial ones whose value is intensionally independent. (In fact, the class of true mathematical and logical propositions has just one member – the proposition that is true in every possible world at every time.)

All non-trivial intensions are said to be *denotata* of empirical sentences (and of other kinds of expressions). Their truth values may differ due to other logically possible circumstances or over time. Anyway, one may find differences also among empirical sentences. The sentence „Lukáš Bielik does not own a house“ is actually true now. But, though improbable, there is a possibility that this sentence will happen to be false in the future. Contrary to it, the sentence „Light travels at a constant speed of 299 792,458 km/s in vacuum“ is not only considered to be true in our world at some times; we firmly suppose that the sentence (hence, the proposition) is true at all times in our world. Thus TIL enables us to distinguish also between those (and other) kinds of empirical sentences.

We say a word about it in a moment.

## 3 Complementary Viewpoints

Here we come to the final part of our enterprise. Having considered various attempts how to identify laws of nature and how to demarcate them from other facts and processes we may reevaluate grains of truth involved in these attempts. At the logical and methodological level, TIL is very helpful here.

In what follows I try to highlight several complementary aspects of a possible solution to this problem.

### 3.1 Grains of Truth

The Regularity conception ascribes the regularity attribute, as an important quality, to the laws of nature. However, the explicatory apparatus of the theory is so weak that it is hard to distinguish potential kinds of regularities and potential (compound) objects to which the regularity attribute is ascribed. We have seen that it is possible to distinguish several different contexts in which regularity plays a role. The specification of the respective kinds of regularity may show what is its role in the discussion on the demarcation problem.

The Web-of-laws conception has revealed that the whole body of scientific framework in which the laws of nature are formulated is all-important. This idea enables us to explain why we postulate also the laws that are about the properties unexemplified in our universe. Given the apparatus of first ordered logic, suppose that a theory involves, among other things, the following two formulas that can be appropriately interpreted:

(EP) $\neg(\exists x)\ \phi(x)$
(CP) $(\exists x)\ \phi(x) \rightarrow [(\forall x)\ \phi(x) \rightarrow \psi(x)]$.

Both formulas (or, rather, sentences) may belong to one and the same theory. Even if this is the case, their theoretical status may differ. For example, the sentence of the form (EP) may get some kind of empirical support from our observation or experimentation, even though it is a postulate of the theory. We may have good empirical grounds for holding that there is no empirical object that is not influenced by physical forces. On the other hand, if there were such a condition, then every such object would have such-and-such properties. But the (possible) situation described by a sentence of the form (CP) is neither observed nor experimentally tested. Nevertheless, it may be a theoretical consequence of other principles and assumptions that can themselves be supported by empirical tests. So the conjunction of (EP) and (CP) is assumed to be true in the theory, although their conjuncts may have different kinds of empirical or theoretical support.

The lesson seems to be clear. The identification of laws of nature is connected to other theoretical assumptions and their role as well as their theoretical status may differ across different theories.

Finally, the universals conception makes it clear that some kind of physical necessitation has to be explicated in considering the problem of laws. The extensionalistic logical framework is far from being satisfactory for distinguishing law-like from non-law-like regularities, as universals theorists point out. Nevertheless, their own explanation is still incomplete and problematic as we tried to demonstrate in section 1.3.

These ideas can be useful for reconsideration of the identification and demarcation problem of laws of nature. Before deepening these insights it might be fruitful to explicate, from the viewpoint of TIL, law-like sentences at their logical and semantic level.

### 3.2 Logical Explication of Lawfulness

Given Materna's suggestion how to explicate logical as well as other kinds of modalities in TIL (see, e.g., Materna 2005 or Gahér 2003), we are theoretically equipped to remove some of the confusions that arose when discussing the questions of necessity and contingency of laws of nature.

In the modern history of philosophy there are camps of theorists who suppose the laws to be contingent (see as an example Ayer's 1998) and those who appeal to a kind of necessity in the case of laws of nature (e.g. Kneale's 1957). Now, the necessity traditionally conceived was ascribed only to logical and (some) mathematical sentences (propositions). Nonetheless, there has been a pervasive intuition that a kind of non-logical (say, physical or metaphysical) necessity is needed for explanation of some regular happenings.

Using the apparatus of TIL we can provide illuminating distinctions of logical and empirical sentences on the one hand and law-like and non-law-like empirical sentences on the other hand.[17]

Let us start with logic. If we want to say that a formula (LO) of propositional logic holds necessarily, we analyze its underlying logical-semantic form as (LO*):

(LO) $p \rightarrow p$
(LO*) ${}^0\forall.\lambda w[{}^0\forall.\lambda t[{}^0{\rightarrow}[p_{wt}][p_{wt}]]]$.

(LO*) constructs the truth value True for every proposition $p$.[18] This kind of necessity is undoubtedly foreign to empirical sentences because they denote non-trivial propositions whose truth values may vary due to modal or temporal variability.

17 All the main explicatory ideas are adopted from Materna (2005), except for my suggestion about the characterization of non-lawful empirical generalizations.

18 We neglect a partiality problem here.

Of course, the laws of nature are not logical truths, but they differ in their logical type from empirical sentences denoting singular facts as those described by, e.g., "My car is broken" or "Arvo Pärt is a composer". Here is the construction notation of the former sentence:

(EF*) $\lambda w \lambda t[{}^0\text{Broken}_{wt}\ {}^0\text{My\_Car}_{wt}]$.

The construction ${}^0$Broken *v*-constructs the type $(o\iota)_{\tau\omega}$, viz. a property of individuals, and the construction ${}^0$My_Car *v*-constructs the type $\iota_{\tau\omega}$, viz. an individual role. The complex construction (EF*) *v*-constructs a proposition that is true at those <possible world, time> couples in which the individual car I own is broken and is false in all other couples (or undefined if there is no such a car of mine in a given possible world or time).

Now what about empirical sentences which are supposed to be law-like? Materna's explicatory proposal is to take the law-like empirical sentences to denote so-called "eternal contingent propositions"; propositions of this kind hold in those possible worlds in which the laws hold at every time.[19] So, every law-like sentence denotes an object of type $(o\omega)$. An example might help.

Suppose we want to explicate Ohm's law expressed by the following formula:

(OL) $U = I \,.\, R$

where 'U' is a magnitude of electric voltage, 'I' is an intensity of electric current, and 'R' is a magnitude of resistance. Given the assumption that 'U', 'I', 'R' are of the same type – $\tau_{\tau\omega}$ (a type of magnitude), multiplication function 'mult' is of a type $(\tau\tau\tau)$ and equality function '=' of a type $(o\tau\tau)$, the construction expressed by this law-like formula (or sentence) runs:

(OL*) $\lambda w[{}^0\forall.\lambda t[{}^0{=}\ {}^0U_{wt}[{}^0\text{mult}\ {}^0I_{wt}\ {}^0R_{wt}]]]$.

19 In (2005) Materna adds one condition for distinguishing eternal contingent propositions (the law-like ones) from those that hold eternally after some moment $t_m$ (the non-law-like). I omit this addition here. Nonetheless, latter kind of propositions is eliminable when an extra-logical condition is adopted: *The law-like sentences do not contain references to particular times.*

The construction *v*-constructs those worlds in which at every time it holds that the value of electric voltage, in that world and at that time, is equal to the product of the values of current's intensity and resistance. It is an eternal, but logically contingent proposition.[20]

This explication seems to capture the prevalent intuition that laws of nature are different both from usual singular (empirical) facts and from logical or mathematical truths.

I add also an example of non-law-like empirical regularity; it shows its different type. Consider the sentence:

(ER) Every Slovak man, who is married, has just one wife.

For the sake of simplicity, take the expression „Slovak man" to denote the property of individuals; similarly for „being married" and „has just one wife".[21] Let $t^*$ be a multiple variable denoting particular moments $T_1 \ldots T_n$ from the chronology of a given possible world (dependently on valuation). Then, perhaps, (ER) expresses the following construction:

(ER*) $$\lambda w[^0\forall.\lambda t^*[^0\forall.\lambda x[^0\rightarrow [^0\wedge\ [^0Slovak\_man_{wt^*}\ x][^0Married_{wt^*}\ x]] [^0Has\_just\_one\_wife_{wt^*}\ x]]]].$$

The sub-construction '$\lambda t^*$ [...$t^*$...]' *v*-constructs a proper subclass of the class of (all) times. The whole construction *v*-constructs the proposition that is true in those possible worlds in which for every time from a given interval of chronology of that world it holds that every individual who is a Slovak man and is married at $\langle w,t^*\rangle$, has just one wife at $\langle w,t^*\rangle$. In the case of non-law-like regularities the relevant time interval is a proper subclass of the set of all time points from the chronology of a given possible world. So, the sentence representing non-law-like regularity is not eternally true. Well, from the pragmatic perspective, many non-law-like regularities are such that we are not

20 Of course, there is only a finite interval of values for which the law-like proposition holds. But this is due to other laws of nature and idealizational assumptions.

21 The literal meaning of (ER) is a bit different but for our purpose it is simply convenient to hold all three compound expressions to denote (different) properties of individuals.

capable to identify what is the last moment at which they hold but fail to hold afterwards. Nevertheless, I believe that this is not a serious threat to our proposal.

Now, I suppose, we can clearly see some of the differences between the logical types of empirical as well as non-empirical sentences and their underlying constructions.

### 3.3 Complementary Approach – the Levels of Demarcation

Finally, we come to the questions concerning identification and demarcation of laws of nature with respect to different levels and dimensions of perspective.

We should emphasize, at first, that *the* problem of *identification* and *demarcation* of laws of nature is an *epistemological* or *methodological problem* and differs from *the question of the reality* of laws of nature. Here we have supposed the reality of laws of nature and focused, rather, on the possible criteria of their identification.

Of course, different philosophical conceptions pay attention to different aspects of lawlikeness. What I want to highlight is that every such an enterprise has many implicit assumptions, some of which are explicitly stated in other conceptions. The following notes are by no means exhaustive.

Evidently, we have seen that a law-like sentence considered as an (approximate) representation of a law of nature expresses a construction of the form

(LN*) $\lambda w[{}^0\forall.\lambda t[p_{wt}]]$,

where $p$ is a type of proposition. The construction (LN*) may be conceived as representing a kind of relevant regularity. However, this type of *temporal regularity* or, better, *eternality* is a *logical aspect* of laws of nature. It should be clearly distinguished from other kinds of regularity some of which are mentioned in subsection 1.1. Such a construal corresponds to the intuition emphasized by A-D-T according to which the laws of nature are not (only) about the actual (exemplifying) objects, but also about all potential exemplifiers in (a) given possible (our actual) world(s) at every time.

The assumption of law-like regularity is, obviously, a kind of *metaphysical presupposition*. It would be naïve to believe that such assumptions are behind the practice of science. On the contrary, they are implicit components of almost every scientific theory. Metaphysical assumptions may appeal to some *causal mechanism* that is "ontologically" responsible for the respective temporal eternality of law. The reasons for holding these assumptions may be theoretically fruitful (for the case of explanation or prediction). They have to be, however, backed up by reliable empirical support gained by different kinds of scientific methods. The concept of *theory* seems to be indispensable here. Different parts of a theory may denote different types of objects with distinct empirical statuses. As we pointed out in subsection 3.1, law-like statements (or sentences) are but a segment – though a very important one – of theoretical body. Therefore, they can play different roles in different theories. For example, the First Kepler's Law has both a descriptive as well as a predictive theoretical potential, but its explanatory power is limited due to its non-causal character; on the other hand, the Law of Universal Gravitation have a potential not only to predict the trajectories of objects but also to explain why they are such-and-such. Hence, a theory may involve different lawful regularities with different *theoretical* functions.

Finally, there is experimental experience in search for laws of nature. The regularity of laws is, from this point, best conceived as *invariance* in experimentally tested behavior or as *invariance* in behavior predicted by (or derived from) a theory and some additional assumptions. If not the law-like sentences themselves, then at least the assumptions theoretically connected with them have to get some empirical support, seen at best as the aforementioned invariance. When we have experience or make a calculation demonstrating that some happenings are permitted in nature while others are forbidden, we have potential empirical evidence for metaphysical assumptions of scientific theories. These *epistemological activities* are made by scientists, of course, and their explication would need a larger place than that which has been reserved for different goals here.

After all, the practice of identification and demarcation of laws of nature has a multi-faceted character with mutually interconnected levels and dimensions. It is not a business of philosophy of science to say which statements express laws of nature. However, when considering the question of appropriate demarcation criteria, there is a room for such a philosophical enterprise. Still, we should recall that the room has several corners.

*Katedra logiky a metodológie vied*
*Filozofická fakulta UK*
*Šafárikovo nám. 6*
*Bratislava*
*bielik@fphil.uniba.sk*

**References**

AYER, A. J. (1998): What is a law of nature? In: Curd, M. – Cover, J. A. (eds.): *Philosophy of Science. The Central Issues.* New York – London: W. W. Norton & Company, 808 – 825.

ARMSTRONG, D. M. (1983): *What is a Law of Nature*? Cambridge: Cambridge University Press.

CMOREJ, P. (2001): *Na pomedzí logiky a filozofie*. Bratislava: Veda.

DRETSKE, F. I. (1998): Laws of Nature. In: Curd, M. – Cover, J. A. (eds.): *Philosophy of Science. The Central Issues.* New York – London: W. W. Norton & Company, 826 – 845.

DUŽÍ, M. – JESPERSEN, B. – MATERNA, P. (2010): *Procedural Semantics for Hyperintensional Logic (Foundations and Applications of TIL)*. Springer.

GAHÉR, F. (2003): Logical, Scientific and Real Possibility. In: Rott, H. – Horák, V. (eds.): *Possibility and Reality – Metaphysics and Logic*. Frankfurt a.M – London: Ontos Verlag, 169 – 186.

HUME, D. (1960): *A Treatise of Human Nature*. Selby-Bigge, L. A. (ed.). Oxford: The Clarendon Press.

HUME, D. (2007): *An Enquiry concerning Human Understanding*. Millican, P. (ed.). Oxford – New York: Oxford University Press.

KNEALE, W. (1952): *Probability and Induction*. Oxford: Clarendon Press.

LEWIS, D. (1973): *Counterfactuals*. Blackwell Publishers.

MATERNA, P. (2005): Ordinary Modalities. *Logique & Analyse* 48, No. 189 – 192. 57 – 70.

MATERNA, P. (1998): *Concepts and Objects*. Helsinki: Acta Philosophica Fennica, 63.

MILL, J. S. (1886): *System of Logic Ratiocinative and Inductive*. Elibron Classics Replica Edition.

MITTELSTAEDT, P. – WEINGARTNER, P. A. (2005): *Laws of Nature*. Springer.

MOLNAR, G. (1969): Kneale's Argument Revisited. *The Philosophical Review* 78, No. 1, 79 – 89.

PSILLOS, S. (2002): *Causation and Explanation*. Montreal – Kingston, Ithaca: McGill-Queen's University Press.

RACLAVSKÝ, J. (2009): *Jména a deskripce: logicko-sémantická zkoumání.* Olomouc: Nakladatelství Olomouc.

RAMSEY, F. P. (1978): Universals of Law and of Fact. In: Mellor, D. H. (ed.): *Foundations. Essays in Philosophy, Logic, Mathematics and Economics*. Routledge and Kegan Paul, 128 – 132.

TICHÝ, P. (1988): *The Foundations of Frege's Logic*. Berlin: de Gruyter.

TOOLEY, M. (1987): *Causation: A Realist Approach*. Oxford: Oxford University Press.

WOODWARD, J. (2003): *Making Things Happen: A Theory of Causal Explanation.* Oxford – New York: Oxford University Press.