European Review, Vol. 22, No. S1, S145–S162

doi:10.1017/S1062798713000811

Natural Law and Universality in the Philosophy of Biology

ALEXANDER REUTLINGER

Ludwig-Maximilians-Universität München, Fakultät für Philosophie, Wissenschaftstheorie und Religionswissenschaft, Ludwigstr. 31 Room 130, 80539 Munich, Germany. E-mail: Alexander.Reutlinger@lrz.uni-muenchen.de

Several philosophers of biology have argued for the claim that the generalizations of biology are historical and contingent.[1–5] This claim divides into the following sub-claims, each of which I will contest: first, biological generalizations are restricted to a particular space-time region. I argue that biological generalizations are universal with respect to space and time. Secondly, biological generalizations are restricted to specific kinds of entities, i.e. these generalizations do not quantify over an unrestricted domain. I will challenge this second claim by providing an interpretation of biological generalizations that do quantify over an unrestricted domain of objects. Thirdly, biological generalizations are contingent in the sense that their truth depends on special (physically contingent) initial and background conditions. I will argue that the contingent character of biological generalizations does not diminish their explanatory power nor is it the case that this sort of contingency is exclusively characteristic of biological generalizations.

1. Introduction: The Universality of Laws

Many philosophers of biology are convinced that there are important differences between (fundamental) physics and the biological sciences. One salient way in which biology is unlike physics – these philosophers claim – concerns the features of generalizations that play an epistemic role in the scientific practice of these disciplines. It is a majority view in philosophy of biology that (fundamental) physics states universal and exceptionless laws, while the biological sciences rely on non-universal and physically contingent generalizations[1–7] This majority view in the philosophy of biology converges with the results of the literature on *ceteris paribus* laws since the mid-1990s: generalizations in the so-called 'special sciences' (such as neuroscience, psychology, sociology, economics, and the life sciences, and so on) have different features than the laws of (fundamental) physics (cf. Ref. 8 for a survey).[9]

In this paper, I will agree with these philosophers that the dynamical laws in fundamental physics and the laws in the special sciences differ in the way they describe.[10] However, despite the differences between laws in fundamental physics and generalizations in the special sciences (including biology), most philosophers believe that, in physics as well as in the special sciences, laws are important because they are statements used to explain and to predict phenomena, they provide knowledge how to successfully manipulate the systems they describe, and they support counterfactuals. Statements that are apt to play these roles in the sciences I call *lawish.* Similarly, Mitchell[11,12] characterizes generalizations in the biological sciences (and in the special sciences in general) as 'pragmatic laws' in virtue of performing at least one these roles.

One might begin to wonder: what exactly is the target of philosophers of biology who stress differences between the features of generalizations in fundamental physics and in the biological sciences? Philosophers of biology are worried that logical-empiricist views have created certain philosophical prejudices about how we think about laws of nature (e.g. Refs 1 and 5). In the early debate on laws of nature, empiricist philosophers of science believed that *lawlikeness* was the crucial concept in order to find out which statements are law statements and which are not. Most importantly for our purposes, lawlikeness is commonly associated with universality (Ref. 13, p. 301). Philosophers of biology argue that the logical-empiricist view is a philosophical prejudice that ought to be overcome because it has been developed by focusing exclusively on physics while ignoring the biological sciences and other special sciences. It is simply false to believe that the generalizations of the latter scientific disciplines are universal.

By contrast to lawlikeness, I use 'lawish' in the following way: a general statement is lawish if it is of explanatory and predictive use, successfully guides manipulation, and supports counterfactuals. Contrary to the traditional understanding of laws, being lawish does neither require universality nor other characteristic features of fundamental physical laws (such as the feature of satisfying symmetry principles). It is a matter of convention whether one would still want to use the term 'law' for non-universal (i.e. not lawlike) general statements.[14] In other words, whether one wishes to refer to lawish statements by the honorific term 'law' is merely a verbal issue and not an interesting philosophical problem. One can either use a new term for lawish, non-universal explanatory, general statements. For instance, Woodward and Hitchcock[15] introduce the concept of an explanatory generalization. Or, as I maintain in this paper, one can insist that if a statement plays a lawish role then it shares sufficiently many properties with universal laws in order to be called a law. Christopher Hitchcock and James Woodward admit that their account may be read as a *reconceptualization* of lawhood (cf. Ref. 15, p. 3). In order to avoid a fruitless quarrel about verbal issues, my strategy in this paper will be to address two questions.

1. Are the laws of biology non-universal – and, if so, in which sense?
2. If the generalizations of biology are indeed in some sense non-universal, does this fact question their ability to play a lawish role?

Before I go on to answer these questions, let me provide a few examples of candidates for lawish generalizations in biology. The following five generalizations are classic examples in the debate on whether there are any laws of biology.

- *Mendel's Law of Segregation*. 'In a parent, the alleles for each character separate in the production of gametes, so that only one is transmitted to each individual in the next generation' (Ref. 16, p. 36).

- *Hardy-Weinberg-law*. 'In an infinite, randomly mating population, and in the absence of mutation, immigration, emigration, and natural selection, gene frequencies and the distribution of genotypes remain constant from generation to generation' (Ref. 16, p. 36, cf. Ref. 1, p. 221).
- *The Krebs-cycle-generalization*. 'In aerobic organisms, carbohydrate metabolism proceeds via a series of chemical reactions, including the eight steps of the Krebs cycle.' (Ref. 1, p. 219)
- *Bergmann's rule*. 'Given a species of warm-blooded vertebrates, those races of the species that live in cooler climates tend to be larger than those races of the species living in a warmer climates' (Ref. 1, p. 224).
- *Allen's rule*. 'Given a species of warm-blooded vertebrates, those races of the species that live in cooler climates have shorter protruding body parts like bills, tails, and ears than those races of the species that live in warmer climates' (Ref. 1, p. 224).

Recently, the debate has been enriched by a large number of interesting examples of lawish generalizations (cf. especially Refs 17–21). It is important to present a few of these example in order to prove the point that the above-listed classic examples of lawish generalizations are not an exceptional (and sometimes even outdated, no longer accepted) part of scientific practice in biology. Quite to the contrary, biology seems be full of lawish generalizations (which, admittedly, do not live up to the standard of lawlikeness).

The area law. 'The equilibrium number S of a species of a given taxonomic group on an island (as far as creatures are concerned) increases [polynomially][22] with the island's area [A]: $S = cA^z$. The (positive-valued) constants c and z are specific to the taxonomic group and island group' (Ref. 17, pp. 235f)

The classic Lotka-Volterra Model. 'The classical Lotka-Volterraprey–predator model's equations are the following. Prey's growth equation is

$$\mathrm{d}N_1/\mathrm{d}t = rN_1 - bN_1N_2$$

Predator's growth equation is

$$\mathrm{d}N_2/\mathrm{d}t = ebN_1N_2 - cN_2$$

In the equations, r is the intrinsic growth rate of prey (in the absence of predation), c is the intrinsic death rate of predator (in the absence of their prey), b is the predation rate coefficient, e is predation efficiency, N_1 is the population size of prey at time t, and N_2 is the population size of predators at time t. These equations describe the dynamics in which populations of both prey and predators exhibit periodic oscillations' (Ref. 20, p. 222).

The Volterrarule. 'Any biotic or abiotic factor that both *increases* the death rate of predators and *decreases* the growth rate of their prey has the effect of *decreasing* the predator population size, whereas the population size of its prey *increases*' (Ref. 20, p. 228).

Kleiber's rule. 'Basal metabolism, an estimate of the energy required by an individual for the basic processes of living, varies as $aW^{0.75}$, where W is its body size [and a is a constant – A.R.]' (Ref. 20, p. 219).

The exponential population growth model. 'Population growth is density independent, and it can be described by the equation

$$N_t = N_0 e^{rt}$$

where N_t is the population size at time t, N_0 is the initial size of the population, and r is the growth rate of the population, called the intrinsic rate of increase' (Ref. 20, p. 212).

Mechanistic models. In the recent literature, the focus is on a large class of generalizations describing the steps in a mechanism such as the mechanism of photosynthesis, the LTP mechanism (Ref. 4).

Generalizations like these are believed to be *lawish*, although they are not universal generalizations.

So, why is it important to understand lawishness? One weighty reason stems from the conceptual connection of laws to causation and explanation. As mentioned above, according to the empiricist interpretation the most important feature of lawlikeness is *universality*. The idea to understand lawhood mainly in terms of universality has led many theories of causation and explanation to rely on universal laws. This assumption turns out to be problematic: the central challenge for any theory of non-universal laws in the biological sciences is to account for their apparent lawish function (in the sense introduced above). If we are not able to provide an explication of non-universal laws, then (at least) the philosophy of biology faces a severe problem concerning causation and explanation in its domains. Many theories of causation and explanation in their *standard* form presuppose universal laws of nature (cf. Ref. 23, p. 99 for a detailed discussion). If we do not want to give up the immensely plausible opinion that the biological sciences refer to causes and provide explanations (Assumption 1) *for purely philosophical reasons*, then we are in need of a theory of non-universal lawish generalizations.

In this paper, I will proceed as follows: in Section 2, I will provide several alternative meanings of the ambiguous concept of universality. I suggest that the claims made by philosophers of biology about the non-universality of lawish statements ought to be distinguished into three claims: first, the lawish statements are restricted to a space-time region. Second, the lawish statements are restricted to specific kinds of entities. Third, the lawish statements are true only if special physically contingent initial and background conditions obtain. In Section 3, I argue against the claims that lawish generalizations are historical in sense that they are restricted to a specific spatio-temporal region and specific kinds of entities. In Section 4, I question the view that the feature of contingency undermines the lawish character of a statement. I argue for this claim by showing that the feature of contingency is compatible with four standard accounts of laws in the special sciences (i.e. completer, normality and statistical, invariance, and dispositionalist theories). In Section 5, I summarize the results of the preceding sections. I conclude with an outlook on future research concerning the features of laws describing biological complex systems.

2. What is Universality?

As stated in the introduction, many philosophers of biology believe that the lawish generalizations of biology are – unlike the laws of fundamental physics – not universal.

https://doi.org/10.1017/S1062798713000811 Published online by Cambridge University Press

But what does it mean to be *universal*, and, respectively, to be *non-universal*? It is an astonishing fact that this question is seldom answered in a systematic way (Refs 12, 23–25 are notable exceptions). The lack of a systematic approach is a serious problem, because universality is an ambiguous concept. In accord with Andreas Hüttemann (Ref. 25, pp. 139–141), we may distinguish four dimensions of universality with respect to a law statement.

(1) *First Dimension – Universality of space and time*. Laws are universal_1 iff they hold for all space-time regions.
(2) *Second Dimension – Universality of Domain of Application*. Laws are universal_2 iff they hold for all (kinds of) objects.
(3) *Third Dimension – Universality for External Circumstances*. Laws are universal_3 iff they hold under all external circumstances, i.e. circumstances that are not referred to by the law statement itself. One useful way to interpret Hüttemann's reference to external conditions is to say that laws are true for *all initial* and *background conditions* of the system whose behaviour is described by the law.
(4) *Fourth Dimension – Universality with respect to the Values of Variables*. Laws are universal_4 iff they hold for all possible values of the variables[26] in the law statement. Universality in this sense acknowledges that laws usually are quantitative statements (and, thus, the predicates contained in these statements are to be conceived as variables ranging over a set of possible values).

Paradigm examples of fundamental physical laws (such as Newton's laws, Einstein's field equations, and the Schrödinger equation) are usually taken to be universal in all four dimensions (cf. Ref 24, section 6.1; Ref. 25, pp. 139–141).

The crucial question in this paper is which dimension of universality is at stake when philosophers of biology claim that the lawish generalizations of their discipline are non-universal. Philosophers of biology seem to refer to several dimension of (non-)universality. Hence, we need to disambiguate their claims. I think it is a fair reconstruction to say that three claims with respect to three dimensions of universality prevail in the literature.

1. *Historicity claim I*. The lawish generalizations of biology are historical because they are spatio-temporally restricted (Ref. 3, pp. 755–758). That is, the generalizations are non-universal_1.
2. *Historicity claim II*. The lawish generalizations of biology are historical because they are restricted to certain kinds of objects that exist in a limited space-time region (Ref. 3, pp. 755–758). In other words, the generalizations do not have the feature of being universal_2.
3. *Contingency claim*. The lawish generalizations of biology are true only if (a) certain physically contingent initial and background conditions C obtain; and (b) these conditions C lead to the evolution of those biological entities that biological generalizations in question describe (Ref. 1, pp. 218f).

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> I interpret Beatty's influential evolutionary contingency claim as a special case of non-universality$_3$: lawish generalizations in biology are true only if specific initial and background conditions obtain.

In Section 3, I will argue that we can easily reject *Historicity claim I* and *Historicity claim II*. Hence, the lawish generalizations of biology can indeed be regarded as universal$_1$ and universal$_2$. In Section 4, I will agree with most philosophers of biology that the lawish generalizations are true only if certain physically contingent initial and background conditions obtain. However, I will argue that this kind of contingency does not prevent generalizations from playing a lawish role.

3. Against the Alleged Historical Character of Biological Generalizations

Are the lawish generalizations of biology universal$_1$ and universal$_2$? I think the answer is yes. Being universal$_1$ and universal$_2$ are features that the lawish generalizations of biology and the laws of physics have in common. My answer is in conflict with Rosenberg's historicity claims I and II (see Section 2). Contrary to Rosenberg, I will argue for two claims: first, lawish generalizations in the biological sciences hold for *all* space-time regions (i.e. they are universal$_1$). This kind of universality allows that these generalizations simply lack an application in some space-time regions. Secondly, lawish statements can be formalized such that they quantify over an *unrestricted* domain of objects (if so, they are universal$_2$).

Arguing for these claims might not seem plausible at first glance, because generalizations in the biological sciences are usually interpreted as system laws (Cf. Ref. 27, Essay 6, for the similar notion of a phenomenological law.) Gerhard Schurz (Ref. 24, Section 6.1) introduces the notion of a system of laws as follows: while fundamental physical laws 'are not restricted to any special kinds of systems (be it by an explicit antecedent condition or an implicit application constraint)' (Ref. 24, p. 367), system laws refer to particular systems of a certain (biological, psychological, social, etc) kind *K* in a specific space-time region. Hence, so the usual characterization continues, lawish statements in the special sciences typically have an in-built historical dimension, which the fundamental physical laws lack, because they are restricted to a limited space-time region where the objects of a certain kind *K* exist (for instance, cf. Refs 1 and 3). I will argue that Schurz is absolutely correct in characterizing lawish statements in the biological sciences as being 'restricted to […] special kinds of systems (be it by an explicit antecedent condition or an implicit application constraint)' (Ref. 24, p. 367). However, if one adopts Schurz's characterization of generalizations in biology as system laws, then one is still entitled to believe that these statements are universal$_1$ and universal$_2$. Let me explain why I think Schurz's interpretation of biological generalizations as system laws differs from Rosenberg's spatio-temporally restricted laws. I will argue for this claim in two steps: first I will argue for the universality$_1$ of lawish statements, then for their universality$_2$.

Argument for Universality$_1$

Does Schurz's characterization of system laws imply that the generalizations of biology are non-universal$_1$? No. Simply because a generalization *G* does not have an application in some space-time region *s*, it does not mean that the law does not hold at *s*. In order to be truly non-universal$_1$, G would have to conform to a thought experiment of 'Smith's Garden' by Tooley:

> All the fruit in Smith's garden at any time are apples. When one attempts to take an orange into the garden, it turns into an elephant. Bananas so treated become apples as they cross the boundary, while pears are resisted by a force that cannot be overcome. Cherry trees planted in the garden bear apples, or they bear nothing at all. If all these things were true, there would be a very strong case for its being a law that all the fruit in Smith's garden are apples. And this case would be in no way undermined if it were found that no other gardens, *however similar to Smith's garden in all other respects*, exhibited behaviour of the sort just described. (Ref. 28, p. 686, emphasis added)

According to Tooley, a law L can be spatio-temporally restricted to a space-time region *s* (as the laws in Smith's garden) in the sense that L fails to be true in a situation that is perfectly similar to the situation in *s*, except for the fact that this perfectly similar situation is located in a different space-time region *s** (cf. Ref. 29).

I think the generalizations of biology that are truly non-universal$_1$ would be similar to the laws that are true of various fruit in Smith's garden. But it seems to be a far too strong claim that laws in the biological generalizations are local in the same way as are the laws in Smith's garden. It seems to be a more promising option to say that (a) biological generalizations are universal$_1$, and (b) these generalizations simply lack application in some space-time regions. For instance, Bergmann's rule, the classic Lotka-Volterra Model and Mendel's law of segregation do not hold on Mars, because there are neither warm-blooded vertebrates, nor anything standing in a predator-prey relation, nor cells with alleles. However, this situation does not indicate that Bermann's rule, the classic Lotka-Volterra Model and Mendel's law of segregation are *local* laws – as are the laws of Smith's garden. A better understanding seems to be that these statements happen to have no application on Mars (e.g. if there are no warm-blooded vertebrates on Mars, then the conditions of application for Bergmann's rule are not satisfied; cf. Ref. 30, Section 3). To illustrate my claim in another way, consider the following scenario: suppose we were to find a space-time region *s* that is in biological aspects perfectly isomorphic to Earth (including certain physically contingent initial and background conditions) – that is, the only difference between life on Earth and life in this region *s* is the spatio-temporal location. And suppose further we were to discover that none of the generalizations of current terrestrial biology is true in region *s*. Would we not demand an explanation for this local inapplicability? It is precisely this demand for an explanation that reveals the intuition that Bergmann's rule is quite dissimilar to the laws of Smith's garden.

Argument for Universality$_2$

Does the characterization of lawish statements in the biological sciences as system laws imply that these statements are non-universal$_2$? No, it does not. At first glance, biological generalizations, if viewed as system laws, appear to be non-universal$_2$: special science laws quantify over a restricted domain of objects of a certain kind – not over a domain of objects of all kinds. For instance, consider *Bergmann's rule* once more: 'given a species of warm-blooded vertebrates, those races of the species that live in cooler climates tend to be larger than those races of the species living in a warmer climates' (Ref. 1, p. 224). Bergmann's rule seems to be restricted to warm-blooded vertebrates – it does not make any claim about electrons, atoms, neurons, rational agents, markets, etc. One might get the idea that generalizations of biology refer to a *restricted* domain **D** that is a proper subset of the domain **X** of all things. Bergmann's rule can be formalized as quantifying over a restricted domain **D** of warm-blooded vertebrates (with *d* as an individual variable of domain **D**):

> $\forall(d)$ ((lives in cooler climates)$d \rightarrow$ (tends to be larger than those races of the species living in a warmer climates)d.

But is this really a convincing reconstruction of lawish statements in the special sciences? I can provide an alternative formalization that quantifies over the domain of *all* objects. This formalization interprets the kind of object (here: warm-blooded vertebrates) as a *predicate* and not as a restriction of the domain. In the alternative formalization, *x* is an individual variable for the unrestricted domain **X**:

> $\forall(x)$(is a member of a species of warm-blooded vertebrates)$x \wedge$(lives in cooler climates)$x \rightarrow$ (tends to be larger than those races of the species living in a warmer climates)x.

The alternative, unrestricted formalization of Bergmann's rule is a way to save universality$_2$. By formalizing lawish generalizations in this way, I provide a reason to reconstruct them as generalizations quantifying over all kinds of objects.[31]

This is not a trivial result at all, because philosophers of biology, such as Beatty[1] and Rosenberg,[3] insist that generalizations in the biological sciences should be regarded as (a) being historical in the sense of applying only to a specific space-time region (this is in contradiction with universality$_1$), and (b) as referring to a restricted domain of objects (this contradicts universality$_2$). Contrary to these philosophers, I want to emphasize that one *can* maintain that lawish generalizations in the biological sciences are universal$_1$ and universal$_2$. In other words, the lawish generalizations do not differ from the fundamental laws of physics with respect to the first and the second dimension of universality.

4. The Case for Non-universal$_3$ Generalizations

In Section 2, I interpret Beatty's evolutionary contingency thesis as a special case of non-universality$_3$: lawish generalizations such as Allen's rule, the Volterra rule, and the exponential growth model hold *only if* very specific initial and background conditions obtain. Allen's rule, the Volterra rule, and the exponential growth model do not hold under all (physically) possible initial and background condition. This is why I interpret these lawish generalizations as being non-universal$_3$. There is good evidence for the view that the biological sciences are not an exceptional case in postulating contingent laws. Physically contingent lawish generalizations are of importance in the physical sciences as well. Let me provide a famous example from the physical sciences: the second law of thermodynamics (for short, the Second Law). The Second Law is a non-fundamental physical law. The Second Law is usually taken to play a role in physical explanation, prediction, and manipulation – i.e. it performs a lawish role. The standard formulation of the Second Law is:

> The total entropy of the world (or of any isolated subsystem of the world), in the course of any possible transformation, either keeps at the same value or goes up. (Ref. 32, p. 32)

Craig Callender provides an example as an illustration of the Second Law:

> Place an iron bar over a flame for half an hour. Place another one in a freezer for the same duration. Remove them and place them against one another. Within a short time the hot one will 'lose its heat' to the cold one. The new combined two-bar system will settle to a new equilibrium, one intermediate between the cold and hot bar's original temperatures. Eventually the bars will together settle to roughly room temperature. (Ref. 33)

It is majority opinion that an explanation of why the second law obtains has to require more than just the fundamental laws of physics. According to a tradition originating in the work of Ludwig Boltzmann, one has to rely on physically contingent initial conditions – among other things – in order to explain why macroscopic physical systems conform to the Second Law. An influential proposal for such an initial condition is the so-called past hypothesis, i.e. the claim that the initial macro state of the universe (or an isolated subsystem thereof) was a state of low entropy (Ref. 32, p. 96; Ref. 34, pp. 298–304; Ref. 35, pp. 156–158). The upshot of the Boltzmannian explanation of the Second Law is as follows: the Second Law is a lawish statement which is true only if special initial conditions (expressed by the past hypothesis) obtain – and these special initial conditions are a physically contingent fact with respect to the fundamental dynamical laws of physics. (Cf. Refs 53 and 54 for further examples of physically contingent lawish statements.)

The question I would like to answer in this section is the following: if the generalizations of biology are indeed non-universal$_3$, does this fact undermine their ability to play a lawish role? I will provide arguments for the following answer: no, a generalization might be non-universal$_3$ and lawish at once. I will argue for this claim by showing that several standard theories of lawish statements (or *ceteris paribus* laws) are consistent with the fact that the truths of some lawish statements depend on whether special initial and background conditions obtain (cf. Ref. 8 for a survey of these and other accounts of *ceteris paribus* laws).

(i) Completer Accounts

The basic idea of completer approaches consists of regarding lawish generalizations in the biological sciences – such as Bergmann's rule, the area law, the Volterra rule, and so on – to be incomplete as they stand. Adding missing conditions to the antecedent of the law statement completes the generalizations. The guiding thought is that the completed antecedent implies the consequent of the lawish statement. Jerry Fodor motivates the completer account of laws in the special sciences (including the biology) as follows:

> Exceptions to the generalizations of a special science are typically inexplicable from the point of view of (that is, in the vocabulary of) that science. That's one of the things that makes it a *special* science. But, of course, it may nevertheless be perfectly possible to explain the exceptions *in the vocabulary of some other science*. […]. On the one hand

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> the [special sciences'] ceteris paribus clauses are ineliminable from the point of view of its propriety conceptual resources. But, on the other hand, we have – so far at least – no reason to doubt that they can be discharged in the vocabulary of some lower-level science (neurology, say, of biochemistry; at worst physics). (Ref. 36, p. 6)

Fodor's idea is that the additional, completing factors whose existence is required by the *ceteris paribus* clause cannot be entirely specified within the conceptual resources of, for instance, biology. However, the completion can (at least in principle) be achieved within the vocabulary of some fundamental science such as neurophysiology or physics. A physical microdescription of the antecedent condition A is called a realizer of A (the same A may have several different realizers). Fodor defines a completer more precisely:

> A factor C is a completer relative to a realizer R of A and a consequent predicate B if:
> (i) R and C is strictly sufficient for B
> (ii) R on its own is not strictly sufficient for B
> (iii) C on its own is not strictly sufficient for B. (cf. Ref. 37, p. 23)

Based on this notion of a completer, Fodor defines the truth conditions of a cp-law as follows:

> 'cp(A→B)' is true if for every realizer R of A there is a completer C such that (A ∧ C)→B. [Cf. Refs 23, 38 and 39 for variants of the completer account.]

The crucial question for my purposes is whether the completer approach is compatible with lawish generalizations that have the feature of being non-universal$_3$. The answer is yes, I believe. The natural place for listing the specific physically contingent initial and background conditions – that Beatty (1995) emphasizes – is the completer condition C. For instance, in the case of Allen's rule the completer consists of certain physically contingent initial and background conditions without which a species of warm-blooded vertebrates that live in cool climates would not have evolved. It is a controversial matter whether adding the evolutionary history to the antecedent of the lawish generalization is strictly sufficient for the truth of the consequent of the law statement (cf. Refs 18 and 40 versus Ref. 21).[41] However, what matters most for the problem that this paper is concerned with is that there is nothing in the completer account itself preventing lawish generalizations from being dependent on specific initial and background conditions.

(ii) Normality and Statistical Accounts

The main idea of normality theories consists of advocating the following truth conditions for laws in the biological sciences: Allen's rule is a true lawish generalization if it is normally the case that given a species of warm-blooded vertebrates, those races of the species of warm-blooded vertebrates that live in cooler climates have shorter protruding body parts, such as bills, tails, and ears, than those races of the species that live in warmer climates (cf. Ref. 8, Section 8). Schurz (Refs 42; 24, Section 5) analyses lawish statements in biological sciences as *normic* laws of the form 'As are normally Bs'. Schurz explicates normality in terms of a high probability of the consequent predicate, given the antecedent predicate, where the underlying conditional probabilities are objective statistical probabilities. According to the statistical consequence thesis, normic laws imply numerically unspecified statistical generalizations of the form 'Most As are in fact Bs', by which they can be empirically tested.

So, is it compatible with the normality account that the truth of lawish statements of biology depends on specific physically contingent initial and background conditions? Here the answer is also positive: normality statements can have a complex antecedent which lists further conditions. In analogy with the completer approach, these conditions might include those physically contingent conditions without which – in the case of Allen's rule – warm-blooded vertebrates would not have evolved in a cool climate.

An analogue strategy can be applied to the statistical approach to lawish generalizations proposed by Ref. 43. Their view is closely related to Schurz's normic account. According to Earman and Roberts, a typical special science generalization 'asserts a certain precisely defined statistical relation among well-defined variables' (Ref. 43, p. 467). That is, special science laws are *statistical generalizations* of the following form: 'in population H, a variable P is positively statistically correlated with variable S across all sub-populations that are homogeneous with respect to the variables $V_1, \ldots, V_n$' (Ref. 43, p. 467). The obvious place to mention the physically contingent conditions without which, for instance, warm-blooded vertebrates would not have evolved in a cool climate are the variables $V_1, \ldots, V_n$. It is worth pointing out a genuine feature of normic and statistical accounts: unlike in the case of completer accounts, it is not the case that a proponent of the statistical and the normic account claims that the antecedent of the lawish statement is sufficient for the consequent.

Moreover, and most likely in agreement with Beatty and Rosenberg, Schurz[42] defends the statistical consequence thesis by appealing to an *evolution theoretic argument*.[44] Schurz argues that evolutionary systems are self-regulatory systems whose self-regulatory properties have been gradually selected according to their contribution to reproductive success. He claims that the temporal persistence of self-regulatory systems is governed by a certain range of 'prototypical norm *states*', in which these systems constantly have to stay in order to keep alive. According to Schurz, regulatory mechanisms compensate for disturbing influences coming from the environment. Although the self-regulatory capacities of evolutionary systems are the product of a long adaptation history, they are not perfect. Some organisms may be dysfunctional and their normic behaviour may have various *exceptions*. However, Schurz claims, it has to be the case that these systems are in their prototypical norm states in the high statistical majority of cases and times. For otherwise, these systems would not have survived in evolution.

The upshot of this discussion is that the normality account is not merely compatible with non-universality$_3$. In fact, one of its main proponents, Gerhard Schurz, even provides an evolution-theoretic argument in favour of the account. If Schurz's argument is sound, then it implies that normic laws are a direct result of biological evolution.

(iii) Invariance Accounts

In accord with invariance theories, the distinctive feature of lawish generalization is their invariance. Invariance is the feature that separates lawish and accidentally true generalizations. A generalization is invariant if it holds for some, possibly limited, range

https://doi.org/10.1017/S1062798713000811 Published online by Cambridge University Press

of the possible values of variables figuring in the generalization. According to Woodward and Hitchcock (Ref. 15, p. 17) and Woodward (Ref. 45, p. 250) a statement *G* is minimally invariant if the testing intervention condition holds for *G*. The testing intervention condition states for a generalization *G* of the form $Y = f(X)$:

(1) there are at least two different possible values of an endogenous variable *X*, x_1 and x_2, for each of which *Y* realizes a different value (y_1, y_2) in the way that the function f in *G* describes; and
(2) the fact that *X* takes x_1 or, alternatively, x_2 is the result of an intervention.

Take the *Volterra rule* as an example of an invariant generalization. According to Woodward and Hitchcock's account, the Volterra rule is minimally invariant if there is an intervention ('any biotic or abiotic factor') such that the death rate of predators (counterfactually) increases and the growth rate of their prey (counterfactually) decreases, then the predator population size decreases and the population size of its prey increases.

So again, is the invariance account of lawish generalizations compatible with the contingency claim? Yes, it is. Invariance is defined relative to a set of variables (such as death rate of predators, population size, and so on) and a set of functions relating the variables (such as an increase-decrease-function). An invariantist is free to embrace the view that biological entities (e.g. rabbits and foxes) to which these variables apply have evolved. And she is free to say that it is a physically contingent fact that biological entities of this kind have evolved. The crucial point for the advocate of an invariance account is this: given that certain entities of a kind K have evolved, the lawish generalizations about members of K are the invariant generalizations.

(iv) Dispositionalist Accounts

According to the dispositionalist account, a law statement is true if the type of system in question (i.e. those entities to which the law applies) has the disposition that the law statement attributes to the system.[46–48] For instance, the Krebs-cycle-generalization states that aerobic organisms are the kind of system disposed to have a carbohydrate metabolism proceeding via a series of chemical reactions, including the eight steps of the Krebs cycle. The manifestation of this disposition might be disturbed, but aerobic organism still have the disposition for Krebs-cycle-behaviour. That is, dispositionalists reconstruct law statements as statements about dispositions, tendencies, and capacities, etc, rather than about overt behaviour.[49] The claim is that certain kinds of systems have certain kinds of tendencies or dispositions.

Is it the case that the dispositionalist account is compatible with the claim that the lawish generalizations of biology are non-universal$_3$? We can provide a positive answer. The dispositionalist can happily accept that the dispositions of biological systems have evolved and, at the same time, she can maintain that lawish generalizations ought to be interpreted as claims about the dispositions of evolved biological entities, such as aerobic organisms (cf. Ref. 50, for further examples of biological dispositions).

What has been established in this section? I have started out by interpreting Beatty's evolutionary contingency claim as a special case of non-universality$_3$. Then I have pointed out that biology is not the only sciences that relies on generalizations that depend on physically contingent initial conditions (the Second Law is an example from physics). The main result of this section is that four standard theories of lawish statements in the special sciences (i.e. the completer account, the normality account, the invariance and the dispositionalist account) are compatible with the feature of non-universality$_3$. Thus, it might be the case that the generalizations of biology differ from the fundamental physical laws because the former are not true for all initial and background conditions (as Beatty and Rosenberg argue). However, this result does not need to impress us since the generalizations of biology might still play a lawish role. This result requires a qualification: these generalizations play a lawish role to the extent that discussed theories of special science laws can be integrated into theories of explanation, prediction, and manipulation. One can be optimistic about the prospects of a successful integration lawish statements into theories of explanation because several recent theories of explanation do not require universal laws and rely on non-universal generalizations instead.[4,5,45,51]

Before concluding this section, I will add a disclaimer: it is not the case that I have to accept that *every* generalization that is true of evolved biological entities can play a lawish role. In order to support this claim, I can rely on a distinction proposed by Ken Waters.[55] Waters distinguishes two classes of generalizations about evolved entities: the first class of generalizations concerns the *architecture* of a biological entity, i.e. the way it is built (such as 'all major arteries have thick layers of elastic tissues around them', 'all birds have wings', 'all zebras have stripes', and so on). The second class of generalizations describes how a biological entity changes over time. The lawish role seems to be primarily ascribed to members of the second class – the dynamical generalizations (or 'causal' generalizations, to use Waters' terminology). Let me put is more cautiously: it is at least not clear why I would have to accept that *all* architecture-generalizations do in fact play a lawish role in scientific biological practice. The epistemic role of architecture-generalizations might be limited to classifying systems of a certain kind (which is the product of evolution and which might also be described by a dynamical generalization).[52]

5. Conclusion

What has been achieved in the preceding sections? In Section 1, I reconstructed a view held by many philosophers of biology: the generalizations occurring in the biological sciences differ from the fundamental laws of physics, as the latter are typically taken to be universal while the former are not. But what exactly does universality amount to? In Section 2, I attempted to disambiguate 'universal' by suggesting several alternative meanings of the concept of universality. Based on these alternative meanings I propose understanding the claims made by philosophers of biology about the non-universality of lawish statements in the following ways: first, the lawish statements are restricted to a space-time region, i.e. the statements are non-universal$_1$. Second, the lawish statements are restricted to specific kinds of entities, i.e. the generalizations are non-universal$_2$. Third, the lawish statements are true only if very special physically contingent initial and background conditions obtain. I take this kind of contingency to be a special case of non-universality$_3$. In Section 3, I argued against the claims that lawish generalizations are historical in the sense that they are restricted to a specific spatio-temporal region and to specific kinds of entities. I opposed non-universality$_1$ and non-universality$_2$. The upshot is that lawish generalizations and the laws of physics resemble one another because they share the features of universality$_1$ and universality$_2$. In Section 4, I raised objections to the view that the feature of contingency somehow undermines the lawish character of a statement. I argue for this claim by showing that the feature of contingency is compatible with four standard accounts of laws in the special sciences. This compatibility suggests that a contingent generalization G of biology is lawish to the extent to which the presented standard accounts of laws in special sciences permit that G is used for explanatory and predictive purposes, that G guides manipulations, and supports counterfactuals etc. One significant result of this discussion is that it does not matter at all whether one is willing to call, for instance, Bergmann's rule or the exponential growth model a *law*.

References

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2. K. Schaffner (1993) *Discovery and Explanation in Biology and Medicine* (Chicago: University of Chicago Press).
3. A. Rosenberg (2001) How is biological explanation possible? *British Journal for Philosophy of Science*, **52**, pp. 735–760.
4. C. Craver (2007) *Explaining the Brain. Mechanisms and the Mosaic Unity of Neuroscience* (Oxford: Clarendon Press).
5. S. Mitchell (2009) *Unsimple Truths. Science, Complexity and Policy* (Chicago: The University of Chicago Press).
6. S. Mitchell (2002) *Ceteris Paribus* – an inadequate representation of biological Contingency. *Erkenntnis*, **52**, pp. 329–350.
7. A terminological clarification: my focus is on *law statements* rather than on laws themselves. My aim is not to argue for any particular metaphysical claim (such as a regularity view, a dispositionalist account, and so on).
8. A. Reutlinger, A. Hüttemann and G. Schurz (2011) Ceteris paribus laws. In: E. N. Zalta (ed.) *The Stanford Encyclopedia of Philosophy* (Spring 2011 Edition), URL = <http://plato.stanford.edu/archives/spr2011/entries/ceteris-paribus/>.
9. Cf., for instance, J. Earman and J. Roberts (1999) Ceteris paribus, there is no problem of provisos. *Synthese*, **118**, pp. 439–447; J. Earman, J. Roberts and S. Smith (2002) Ceteris paribus lost. *Erkenntnis*, **52**, pp. 281–301; M. Lange (2000) *Natural Laws in Scientific Practice* (New York: Oxford University Press); B. Loewer (2008) Why there *is* anything except physics. In: R. Hohwy and J. Kallestrup (eds) *Being Reduced. New Essays on Reduction, Explanation, and Causation* (Oxford: Oxford University Press), pp. 149–163; J. Roberts (2004) There are no laws in the social sciences. In: C. Hitchcock (ed.) *Contemporary Debates in the Philosophy of Science* (Oxford: Blackwell), pp. 168–185; J. Woodward (2003) *Making Things Happen. A Theory of Causal Explanation* (Oxford: Oxford University Press); J. Woodward (2007) Causation with a human face. In: H. Price and R. Corry (eds) *Causation, Physics, and the Constitution of Reality: Russell's Republic Revisited* (Oxford: Oxford University Press), pp. 66–105; T. Maudlin (2007) *The Metaphysics in Physics* (Oxford: Oxford University Press); M. Strevens (2009) *Depth. An Account of Scientific Explanation* (Cambridge, MA: Harvard University Press); A. Reutlinger (2011)

A theory of non-universal laws. *International Studies in the Philosophy of Science*, **25**, pp. 97–117.

10. Many of the problems I will discuss in this paper would be even trickier if one disagreed with the majority view in philosophy of biology and in the debate on ceteris paribus laws at this point. Some philosophers (e.g. N. Cartwright (1983) *How the Laws of Physics Lie* (Oxford: Oxford University Press); N. Cartwright, (1989) *Nature's Capacities and their Measurement* (Oxford: Oxford University Press); S. Mumford (2004) *Laws in Nature* (London: Routledge)) believe that even fundamental physics deals (at least in part) with non-universal laws. However, this would rather encourage the debate in philosophy of biology: if this were the case, the issue of non-universal laws might turn out to be even more pressing.
11. S. Mitchell (1997) Pragmatic laws. *Philosophy of Science*, **64**, pp. 242–265.
12. S. Mitchell (2000) Dimensions of scientific law. *Philosophy of Science*, **67**, S468–S479.
13. R. Braithwaite (1959) *Scientific Explanation* (Cambridge: Cambridge University Press).
14. This is not to deny that the unique features of laws in physics are a topic of its own philosophical interest. Let me mention two questions of the greatest philosophical interest that are both related to the symmetry principles that constrain the law statements of physics: (a) how can we explain the existence of time-directed processes in a physical world that is governed by time-reversal invariant fundamental dynamical laws (cf. D. Albert (2000) *Time and Chance* (Cambridge, MA: Harvard University Press); B. Loewer (2008) Why there *is* anything except physics. In: R. Hohwy and J. Kallestrup (eds) *Being Reduced. New Essays on Reduction, Explanation, and Causation* (Oxford: Oxford University Press))? (b) Are symmetry principles laws? Are they empirical or a priori statements? Do they govern first-order laws (cf. M. Lange (2009) *Laws and Lawmakers* (New York: Oxford University Press))?
15. J. Woodward and C. Hitchcock (2003) Explanatory generalizations, part i: a counterfactual account. *Nous*, **37**(1), pp. 1–24.
16. A. Rosenberg and D. McShea (2008) *Philosophy of Biology. A Contemporary Introduction* (Routledge: London).
17. M. Lange (2000) *Natural Laws in Scientific Practice* (New York: Oxford University Press).
18. M. Elgin (2006) There may be strict and empirical laws in biology, after all. *Biology and Philosophy*, **21**, pp. 119–134.
19. A. Hamilton (2007) Laws of biology, laws of nature: problems and (dis)solutions. *Philosophy Compass*, **2**, pp. 592–610.
20. J. Raerinne (2011) Generalizations and models in ecology: lawlikeness, invariance, stability, and robustness. Academic dissertation, University of Helsinki. URL: <http://urn.fi/URN:ISBN:978-952-10-6768-6>.
21. J. Raerinne (2011) Allometries and scaling laws interpreted as laws: a reply to Elgin. *Biology and Philosophy*, **26**, pp. 99–111.
22. Lange mistakenly writes 'exponentially'.
23. A. Reutlinger (2011) A theory of non-universal laws. *International Studies in the Philosophy of Science*, **25**, pp. 97–117.
24. G. Schurz (2002) Ceteris paribus laws: classification and deconstruction. *Erkenntnis*, **57**, pp. 351–372.
25. A. Hüttemann (2007) Naturgesetze. In: A. Bartels and M. Stöckler (eds) *Wissenschaftstheorie* (Paderborn: Mentis), pp. 135–153.
26. A variable X (in the terminology of statistics and causal modelling) is a function $X{:}D \rightarrow \mathrm{ran}(X)$, with a domain D of possible outcomes, and the range $\mathrm{ran}(X)$ of

possible values of X. For quantitative variables X, ran(X) is usually taken to be the set of real numbers (cf. J. Pearl (2000) *Causality: Models, Reasoning and Inference* (Cambridge: Cambridge University Press); A. Eagle (2011) *Philosophy of Probability. Modern and Contemporary Readings* (London: Routledge), Chapter 0.9). For example, temperature is represented by a variable T that has several possible values such as $T = 30.65°$. However, in the debate on causation philosophers often use qualitative, binary variables with ran(X) = $\{0; 1\}$ – whether a binary variable takes one of its values is taken to represent whether or not a certain type of event occurs (cf. C. Hitchcock (2001) The intransitivity of causation revealed in equations and graphs. *Journal of Philosophy*, **98**, pp. 273–299). On notation: capital letters, such as X, Y, …, denote variables; lower case letters, such as x, y, …, denote values of variables; the proposition that X has a certain value x is expressed by a statement of the form $X = x$, i.e. $X = x$ is a statement about an event-type – cf. J. Woodward (2003) *Making Things Happen. A Theory of Causal Explanation* (Oxford: Oxford University Press).

27. N. Cartwright (1983) *How the Laws of Physics Lie* (Oxford: Oxford University Press).
28. M. Tooley (1977) The nature of laws. *Canadian Journal of Philosophy*, **7**, pp. 667–698.
29. J. Earman (1978) The universality of laws. *Philosophy of Science*, **45**, pp. 173–181.
30. M. Strevens (Forthcoming) Ceteris paribus hedges: causal voodoo that works. *Journal of Philosophy*, URL=<http://www.strevens.org/research/lawmech/CPMechBrev.pdf>.
31. One might want to dispute the claim that even the fundamental laws do not apply to *everything* (contra G. Schurz (2002) Ceteris paribus laws: classification and deconstruction. *Erkenntnis*, **57**, pp. 351–372; and A. Hüttemann (2007) Naturgesetze. In: A. Bartels and M. Stöckler (eds) *Wissenschaftstheorie* (Paderborn: Mentis), pp. 135–153). One might object that the fundamental laws, for instance, do not apply to angels and numbers. However, I think that, even if this were the case, we could preserve the universality$_2$ for the fundamental laws by exactly the same strategy that I just used for preserving universality$_2$ for lawish statements in the special sciences. Further, my arguments do not have to rely on the characterization of fundamental physical laws that Schurz and Hüttemann provide.
32. D. Albert (2000) *Time and Chance* (Cambridge, MA: Harvard University Press).
33. C. Callender (2006) Thermodynamic asymmetry in time. In: N. E. Zalta (ed.) *The Stanford Encyclopedia of Philosophy* (Spring 2011 Edition), URL=<http://plato.stanford.edu/archives/spr2011/entries/time-thermo/>.
34. B. Loewer (2007) Counterfactuals and the second law. In: H. Price and R. Corry (eds) *Causation, Physics, and the Constitution of Reality. Russell's Republic Revisited* (Oxford: Clarendon Press), pp. 293–326.
35. B. Loewer (2009) Why is there anything except physics? *Synthese*, **170**, pp. 217–233.
36. J. Fodor (1974) Special sciences, or the disunity of science as a working hypothesis. *Synthese*, **28**, pp. 97–115.
37. J. Fodor (1991) You can fool some people all of the time, everything else being equal; hedged laws and psychological explanations. *Mind*, **100**, pp. 19–34.
38. P. Pietroski and G. Rey (1995) When other things aren't equal: saving ceteris paribus laws from vacuity. *British Journal for the Philosophy of Science*, **46**, pp. 81–110.
39. T. Maudlin (2007) *The Metaphysics in Physics* (Oxford: Oxford University Press).

https://doi.org/10.1017/S1062798713000811 Published online by Cambridge University Press

40. E. Sober (1997) Two outbreaks of lawlessness in recent philosophy of biology. *Philosophy of Science*, **64**, pp. S458–S467.
41. This controversy is concerned with Lange's dilemma, which I will not address in this paper.
42. G. Schurz (2001) Pietroski and Rey on *ceteris paribus* laws. *British Journal for Philosophy of Science*, **52**, pp. 359–370.
43. J. Earman and J. Roberts (1999) Ceteris paribus, there is no problem of provisos. *Synthese*, **118**, pp. 439–478.
44. One of the problems of Schurz's approach arises as soon as one starts to apply his theory of normic laws to non-biological (e.g. economic) examples. His argument is based on a *generalized theory of evolution* which applies not only to biological evolution but also to cultural evolution. The common domain of the life sciences (which, according to Schurz, include biology, psychology as well as the social sciences and the humanities) are evolutionary systems or their products. One might worry though whether such a *generalized theory of evolution* is sufficiently confirmed.
45. J. Woodward (2003) *Making Things Happen. A Theory of Causal Explanation* (Oxford: Oxford University Press).
46. N. Cartwright (1989) *Nature's Capacities and their Measurement* (Oxford: Oxford University Press).
47. A. Hüttemann (1998) Laws and dispositions. *Philosophy of Science*, **65**, pp. 121–135.
48. A. Bird (2005) The dispositionalist conception of laws. *Foundations of Science*, **10**, pp. 353–370.
49. The main motivations to adopt a dispositionalist theory consist of (a) having a strategy to avoid Lange's dilemma, and (b) explaining why idealized laws can be applied in non-ideal situations (Ref. 8, section 7).
50. A. Hüttemann and M. Kaiser (Forthcoming) Dispositions in biology. In: K. Engelhardt and M. Quante (eds) *Oxford Handbook of Potentiality* (forthcoming).
51. M. Strevens (2009) *Depth. An Account of Scientific Explanation* (Cambridge, MA: Harvard University Press).
52. This distinction might also be regarded as a defence of Schurz's normic approach to lawish generalizations, because Schurz's main example of a normic law is 'normally, birds can fly'. This is an unfortunate choice, I think, since the immediate response to this example is to deny that this statement plays a lawish role. Rather Schurz's example ought to be classified as an architecture-generalization. Schurz's account is strong when applied to dynamical generalizations.
53. J. Roberts (2008) *The Law-governed Universe* (New York: Oxford University Press).
54. M. Strevens (2008) Physically contingent laws and counterfactual support. *Philosophers' Imprint*, **8**.
55. K. Waters (1998) Causal regularities in the biological world of contingent distributions. *Biology and Philosophy*, **13**, 5–36.

About the Author

Alexander Reutlinger earned an MA in philosophy from the Freie Universität Berlin in 2008, and he obtained a PhD from the University of Cologne in 2011 (advisor: Andreas Hüttemann). Since then he has held positions as a visiting fellow at the Center for Philosophy of Science (University of Pittsburgh) and as a postdoctoral research

fellow within the research group Causation and Explanation in Cologne (funded by the German Research Council, DFG). As of October 2013 he joined the Munich Center for Mathematical Philosophy at the LMU Munich. Alexander Reutlinger's research is primarily concerned with philosophical questions at the intersection of philosophy of science and metaphysics. In particular, he works on causation, ceteris paribus laws, probabilistic laws in the special sciences and in physics. His recent research is also on non-causal explanations in the sciences and philosophy of complex systems.