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C. Ulises Moulines
zum 60. Geburtstag

# INHALTSVERZEICHNIS

# VORWORT

Die vorliegende Festschrift ist C. Ulises Moulines gewidmet. Sein 60. Geburtstag ist uns Anlass, einen herausragenden Forscher und akademischen Lehrer zu ehren.

C. Ulises Moulines ist ein echter Weltbürger. Geboren wurde er 1946 in Caracas (Venezuela), wo er auch seine Kindheit verbrachte. Zum Abitur und Studium kehrte Prof. Moulines in die Heimat seiner Eltern, nach Spanien, zurück. 1971 erwarb er in Barcelona einen Magister in Philosophie. Der Wechsel nach München, wo Prof. Moulines 1975 von Wolfgang Stegmüller promoviert wurde, war für seine Philosophie von entscheidender Bedeutung. Mit seiner Doktorarbeit »Zur logischen Rekonstruktion der Thermodynamik – Eine wissenschaftstheoretische Analyse« etablierte sich Prof. Moulines als einer der wichtigsten Vertreter des wissenschaftstheoretischen Strukturalismus, den Stegmüller im deutschen Sprachraum eingeführt hatte. 1976 nahm Prof. Moulines einen Ruf auf eine ordentliche Professur für Wissenschaftstheorie an der UNAM (Mexiko) an, wo er, unterbrochen durch eine Gastprofessur an der Universität Kalifornien in Santa Cruz (1977–1978), bis 1983 lehrte. Im Jahr 1984 kehrte er nach Deutschland zurück, an die Universität Bielefeld, an der er bis 1988 eine Professur für Wissenschaftstheorie innehatte. In dieser Zeit veröffentlichte Prof. Moulines (zusammen mit Wolfgang Balzer und Joseph Sneed) das Buch, das bis heute als Standardwerk des Strukturalimus zu gelten hat: »An Architectonic for Science« (1987). In der Zeit von 1988 bis 1993 nahm Prof. Moulines eine Professur für Wissenschaftstheorie und Geschichte der Naturwissenschaften an der Freien Universität Berlin wahr. Schließlich wurde er im Jahr 1993 als Nachfolger von Wolfgang Stegmüller auf den Lehrstuhl für Philosophie, Logik und Wissenschaftstheorie berufen, wo er bis heute forscht und lehrt.

Prof. Moulines hat zahlreiche Auszeichnungen und Ehrungen erhalten: eine außerordentliche Auszeichnung der Universität Barcelona (1971), den nationalen Preis für wissenschaftliche Forschung im Bereich Sozialwissenschaften (vergeben von der Mexikanischen Akademie der Wissenschaften, 1983), die Ehrenmitgliedschaft der spanischen Sociedad de Lógica, Metodología y Filosofía de la Ciencia (1995), den UNESCO-Lehrstuhl in Philosophie (1996), den Lehrstuhl »Blaise Pascal« der Stiftung der École Normale Supérieure (Paris, 2003). Er ist seit 2004 ordentliches Mitglied der Bayerischen Akademie der Wissenschaften und Ehrenmitglied der katalanischen Gesellschaft für Philosophie. Von 1997–

*Pablo Lorenzano*

# FUNDAMENTAL LAWS AND LAWS OF BIOLOGY*


## Abstract

In this paper, I discuss the problem of scientific laws in general and laws of biology in particular. After reviewing the debate about the existence of laws in biology, I examine the subject in the light of the structuralist notion of a fundamental law and argue for the *law of matching* as the *fundamental law* of genetics.


## 1. Introduction

The aim of the present article is to make a contribution to the discussion about scientific laws in general and laws of biology in particular. First, two arguments against the existence of laws in biology are presented. One is based on their non-universality (Smart 1963), the second one is based on their evolutionary contingency (Beatty 1995). Then two responses to these arguments are rehearsed. The first one consists in submitting them to critical analysis. This approach is chosen by Ruse (1970), Munson (1975), and Carrier (1995), among others. The second one is to defend the existence of laws, or principles, in biology but arguing that they are non-empirical, a priori. This strategy is followed by Brandon (1978, 1982, 1997), Sober (1984, 1993, 1997) and Elgin (2003). Finally, after restricting the discussion to the realm of scientific laws, or laws of science, (as opposed to laws of nature), the subject is examined in the light of the structuralist notion of a fundamental law and the analysis of the statement that, according to the reconstruction of genetics presented by Balzer, Dawe (1990), and later developed by Balzer, Lorenzano (1997) and Lorenzano (1995, 2000, 2002a), the *law of matching* could be seen as the *fundamental law* of genetics.

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## 2. Against the existence of laws in biology I: Smart and universality

Smart (1963) proceeds along the following lines: He begins by characterizing a concept which he calls ›laws in the strict sense‹, assumed to apply to the laws of physics and chemistry. Then he analyzes what are usually considered as laws of biology in order to determine whether they possess the same characteristics as the laws of physics and chemistry. He concludes that there are no laws (in the strict sense) in biology at all, but only generalizations.

Smart characterizes the concept of *law in the strict sense* in the following way – the characterization corresponds roughly to the classical explication of the concept of a *fundamental law* (Hempel, Oppenheim 1948): A proposition is a *law in the strict sense* if and only if it satisfies the following conditions: i) it is universal, i.e. it is a general proposition which only contains universal quantifiers, such as $(x)(Fx \rightarrow Gx)$; ii) its scope is unlimited, i.e. it applies everywhere in space and time; iii) it does not contain either explicit or implicit reference to particular objects, i.e. it neither makes use of proper names nor refers tacitly to proper names; iv) it contains only general terms, i.e. it contains only purely universal predicates (according to the terminology of Popper 1935, sections 14 and 15), also called purely qualitative predicates (Hempel, Oppenheim 1948, 269), which do not refer to any particular object nor any spatial-temporal localization (Smart 1963, 53).

In order to find out whether there are statements in biology that satisfy the four conditions just mentioned, and therefore deserve the name of ›laws in the strict sense‹, or ›fundamental laws‹, Smart proposes the analysis of the so-called ›Mendel's laws‹, which are often used as examples of laws in biology. First of all he considers the following proposition, which – he says – is a proposition that obviously belongs to natural history: ›albinotic mice always breed true‹. Referring to that proposition, Smart states that although in the logician's sense it is general, it is not a law in the strict sense, because it refers implicitly to a particular entity, the planet Earth. Then Smart claims that even if we redefine the term ›mouse‹ without referring to the Earth, but through a series of properties $A_1$, $A_2$, ..., $A_n$, which only mice from the planet Earth possess, it is very likely that the proposition that all those that possess those properties and are albinotic breed true is false. On any other planet belonging to a remote galaxy there could exist a species with these properties which is albinotic but does not breed true. In such a case, this proposition would not be universally true and, therefore, would not have an unlimited scope. We could, thence, conclude that the before mentioned proposition is not a law in the strict sense, or a fundamental law.

If next we consider the so-called laws of genetics, such as Mendel's laws, we shall find not only that we have no certainty of their validity outside a restricted region – the Earth –, but rather that even on this planet exceptions exist. According to Smart, not even the terrestrial populations segregate perfectly according to the so-called ›Law of Mendelian Segregation‹. This is due to a multitude of reasons, the most important of which is the phenomenon of crossing over (Smart 1963, 55–56). The law of Mendelian segregation, allegedly a fundamental law of genetics, is therefore not a law in the strict sense.



## 3. Against the existence of laws in biology II: Beatty and necessity

A different argument against the existence of laws of biology, which has been widely discussed recently, is based on the so-called ›thesis of evolutionary contingency‹. It presupposes a modal analysis of the concept of law (»natural law« or »law of nature«), in terms of nomic, or natural, necessity. According to this analysis, a proposition in order to be considered a law, would have to express more than a true regularity, that is to say, it would not only have to be universal and contingently true but it would also have to possess natural or nomic necessity. However, according to Beatty (1981, 1987, 1995, 1997), generalizations are of two types: Either they »are just mathematical, physical, or chemical generalizations (or deductive consequences of mathematical, physical, or chemical generalizations plus initial conditions)« (Beatty 1995, 46), or they are »distinctively biological« generalizations (Beatty 1995, 47). In the first case they cannot be considered laws of biology. In the second case, they describe contingent outcomes of evolution and therefore do not possess *natural* or *nomic necessity*, and hence should not be considered laws of nature.

Beatty elaborates on a proposal made by Gould (1989) to distinguish two senses of evolutionary »contingency«, that is, two senses in which the agents of evolution can break the rules as well as setting them, and in which nature *fails to necessitate* the truth of biological generalizations: a) the weaker sense – which Carrier (1995) calls ›simple contingency‹ – concerns the dependence of biological generalizations on circumstances in general, according to which »the conditions that lead to the evolutionary predominance of a particular trait within a particular group may change, so that the predominance of the trait declines« (Beatty 1995, 53); simple contingency has as a source mutation, natural selection in changing environments, and random drift of genic frequencies in small populations and/or among selectively equivalent genotypes, among others; and b) the stronger sense – called by Carrier (1995) ›high level contingency‹ – concerns circumstances that fail to determine an outcome with certainty, according to which the generalizations describe »contingent« states of affairs, since »evolution can lead to different results from the same starting point, even when the same selection pressures are operating« (Beatty 1995, 57), due to diverse reasons, among which are »chance« or »random« mutation (the probability of the occurrence of a mutation is in no way proportional to the advantage it confers), »functional equivalence« (there are very different ways of adapting to any one environment), and random drift of genic frequencies in small populations.

This thesis of evolutionary contingency (TEC), Beatty claims, is connected to other issues in philosophy of biology, from which it gains support and acquires sense: the explanatory ideals of biology, especially »theoretical pluralism«, and the nature of controversies in biology, specifically the »relative significance« controversies. Beatty takes theoretical pluralism, according to which »*different items of the same domain require explanation in terms of different theories or mechanisms*« (Beatty 1995, 65), to be typical of biology, in contrast to the theoretical monism of the Newtonian tradition, which tries »to explain a domain of phenomena in terms of as few as possible different mechanisms, and best of all one single mechanism« (Beatty 1995, 68). For Beatty biology is characterized by disputes about »relative significance«, where the gist of the dispute is »the *extent of applicability* of a theory or mechanism within a domain – roughly, the proportion of items of the domain governed by the theory or mechanism – *not* whether the mechanism or theory is *the correct* account of the domain« (Beatty 1995, 66).

According to Beatty, the examples of theoretical pluralism and of relative significance controversies that appear at every level of research in biology give support to TEC in the following sense: since the contingencies of evolutionary history exclude (render impossible) the existence of laws in biology, »it is not surprising that a biologist should be more interested in the *extent of applicability* within its intended domain than in its possible universality within that domain« (Beatty 1995, 67), and »[n]ot expecting universal generalizations to hold within a domain, biologists expect instead to have recourse to a plurality of theories to cover it« (Beatty 1995, 67).

## 4. In defense of laws in biology I: Ruse, Manson, and Carrier on Smart and Beatty

A possible strategy to counter these arguments is to question Smart's analysis of the chosen examples. This is the approach of Ruse (1970) and Munson (1975), for example. Both point out that the sentence »All albinotic mice always breed true« in no way can be presented by a biologist or geneticist as a law in the strict sense or as a fundamental law. According to Ruse, if the statement were taken as a law it would be considered a derived law, obtained from the fundamental laws »Albinotic genes are recessive« and Mendel's Law of Segregation – which, in his formulation, »states that when two organisms mate, each passes on one of its pair of genes (at a particular locus) to the offspring, and (considered just with respect to the locus) there is an equiprobable chance which one of the pair will get passed on« (Ruse 1970, 241) – none of which makes explicit or implicit reference to the Earth. On the other hand, Ruse adds that no definition of a group of organisms (species) needs to make reference, even implicitly, to the Earth, and that in fact no definition would in practice make any such reference (Ruse 1970, 246).



For Munson, Smart's mistake in analyzing the sentence »albinotic mice always breed true« consists in failing to distinguish an instance of a law with the law itself: the statement is in fact an instance of the Mendelian principle that »All diploid organisms homozygous for a recessive trait breed true«, which »involves no reference to any particular species or any particular gene«, and that »is not only logically general, but also spatio-temporally unrestricted« (Munson 1975, 445).

Besides, for Ruse as well as for Munson, Mendelian segregation, which is universal in its form, makes no explicit or implicit reference to any particular object (such as the Earth), is spatio-temporally unrestricted and does not contain any non-general terms. Hence it satisfies all the requisites that a statement must satisfy in order to be called a law in the strict sense according to Smart.

Regarding the existence of exceptions to the law, Ruse points out that the Law of Segregation is not the law that would require modification but rather the Mendelian Law of Independent Assortment, and not due to crossing over but to another phenomenon known as ›linkage‹. Besides, Ruse points out that although it is true that there would be exceptions to the law of segregation, in particular owing to the existence of extra-chromosomal genes, the exception form a very small proportion of the whole, certainly not more extensive the proportion of exceptions one finds in the case of most physical laws (Ruse 1970, 243–244).

On the other hand, we have seen that the thesis of evolutionary contingency, which finds support and acquires sense through »theoretical pluralism«, and the disputes of »relative significance«, is for Beatty sufficient to deny that biological generalizations are laws. But, even though he admits not knowing whether there are physical or chemical laws, he concedes that it is possible that true physical or chemical generalizations might be contingent, maybe not evolutionarily, but »cosmologically« contingent. Indeed, as Carrier (1995) points out, the thesis of evolutionary contingency does not seem to be exclusive of biology in either of the two senses, weak or strong. In the weaker sense, concrete results obtained concerning all scientific laws depend heavily on the initial and boundary conditions chosen. In the stronger sense, the occurrence of random changes that cause evolutionary explanations to be non-predictive is a situation that is also present in quantum mechanics (where it is impossible to predict quantum phenomena; only averages and relative frequencies can be predicted). Furthermore, »theoretical pluralism« and the »relative significance« controversies are more common in physics than Beatty thinks; hence they are not exclusive of biology.

## 5. In defense of laws in biology II: Brandon, Sober, and Elgin on non-empirical or a priori biological laws

A different strategy used to defend the existence of laws or principles in biology – or of statements that, although they do not satisfy the classical explication of the concept of a law, play in biology roles that are equivalent to those traditionally assigned to laws, such as being explanatory – consists in first distinguishing two types of generalizations: empirical generalizations, which may be non-universal and contingent, or of limited nomic necessity, and non-empirical (but explanatory) generalizations. Then it is held that at least some of the biological laws or principles (the more fundamental ones) belong to the second group. This is the strategy followed by authors such as Brandon (1978, 1997), Sober (1984, 1993, 1997) and Elgin (2003).

According to Brandon (1978, 1997), generalizations of this type are schematic laws or schemes of laws that have no empirical content by themselves, that is to say they do not have biological empirical content, but are rather mathematics applied to biological problems and, in this sense, are analytic, but constitute organizing principles in the empirical theories in which they occur and play an essential role in all the explanations these theories provide. But if these generalizations, being schemes of laws, have no empirical content, the same is not true about their conditions of applicability or their instantiations, which are empirical. Brandon (1997) recommends what he calls ›linguistic conservatism‹, consisting in maintaining the classical characterization of law and admitting that other things, distinct from the laws thus characterized, may have explanatory power, whether they be empirical but contingent regularities, or non-empirical generalizations (mentioning as examples of the latter the principle of natural selection, the Hardy-Weinberg law and Galton's explanation of regression to the mean).

In several papers, Sober (1984, 1993, 1997) has argued that the process of evolution is governed by models – such as Fisher's fundamental theorem of natural selection, Kimura's model of neutral evolution, or the Hardy-Weinberg law. They constitute *process laws* characterized by being purely qualitative generalizations that support counterfactuals and describe causal and explanatory relations, stating how systems of a specified type develop through time, in such a way that »given a system that occupies a particular state at one time, a process law describes the probability distribution of the different states the system may occupy some fixed amount of time later« (Sober 1997, 459). They can be known to be true a priori, independently of sense experience (Sober 1984, 65, Sober 1997, 458–459).

However, even though the propositions of the mathematical models of evolutionary biology are a priori, Sober (1984, 1993) emphasizes both: their non-trivial character and their being revisable in the light of experience, i. e. their being empirically testable. They have empirical character, even when they are conceived as tautologies – either because they are mathematical truths or, as in one of the usual interpretations of the principle of natural selection, which he rejects, because they are definitions (Sober 1984, 74; 1993, 69–73) – since knowing if the conditions stipulated by the model apply, i. e. determining whether the model is applicable or not, or whether there are entities that conform to the purported definition (Sober 1984, 81), is an empirical question (Sober 1993, 16, 18, 73).



In the same line of thought, he holds that even when a generalization that is used in an explanation is a mathematical truth, »[t]he explanation *as a whole* is empirical because *other* components of it are« (Sober 1984, 79), since as Duhem and Quine have taught, »[h]ighly theoretical claims issue in observational predictions only when they are conjoined with still further assumptions [...] [which] shows why it can be difficult to see whether a theoretical assertion is empirically testable, since one cannot find this out by examining the claim in isolation« (Sober 1984, 73).

On the other hand, Sober (1997) suggests a way of transforming – by way of making explicit the *ceteris paribus* clause, or rather the *ceteris absentibus* clause (as Joseph 1980 proposes to call it) implicit in the evolutionary models – biological contingent generalizations into non-contingent laws (Sober 1997, 459–461). Thus, by way of a certain »adequate formulation«, the idea of biological (process) a priori laws – or general statements »of the ›if/then‹ type« (Sober 1993) – is related to the thesis of evolutionary contingency mentioned by Beatty. To that end he proposes to represent the thesis of evolutionary contingency in the following way (Sober 1997, 460):

$$\frac{\mathbf{I} \longrightarrow [\text{if } \mathbf{P} \text{ then } \mathbf{Q}]}{t_o \qquad\quad t_1 \qquad\quad t_2}$$

where **I** is the set of contingent initial conditions given at a specified time ($t_o$), making a generalization true during a later time interval ($t_1$ to $t_2$). Since the generalization is true solely because **I** obtained, we could say that the generalization is contingent. »However« continues Sober, »there is another generalization that this scenario suggests, and it is far from clear that this generalization is contingent. This generalization will have the following logical form:

(L) If **I** obtains at one time, then the generalization [if **P** then **Q**] will hold thereafter« (Sober 1997, 460).

We could say, with Schaffner's terminology (Schaffner 1980, 1993), that this procedure allows us to »freeze« the »historical« accidents into »nomic universality«,[1] although an a priori one.

[1] For a more extended discussion of Schaffner's treatment of accidentality and/or necessity, as well as other aspects of this author's proposals, see Lorenzano 2002c.

More recently, using Sober's analyses, and taking the Hardy-Weinberg law as an example, Elgin (2003) maintains the existence of a priori biological laws. His argument consists mainly in affirming that non-empirical or a priori biological generalizations »figure in explanations and predictions in biology in a similar way that physical laws do in explanations and predictions in physics« and that while it is usual in the debate about laws of nature to agree that »laws must be empirical and universal«, »we either have to stick with the empirical requirement and say that such a priori biological generalizations are not laws of nature; or we take such a priori biological generalizations as evidence that the empirical requirement is too strong. I favor the latter. One of the implications of giving up this requirement is that biology has laws« (Elgin 2003, 1381).

## 6. The notion of fundamental law in the structuralist conception of theories

In previous sections we have summarized the discussion about the existence of laws of biology, which hinges on issues such as universality, necessity and the a priori character of biological laws. In this section we shall discuss the notion of a fundamental law proposed in the framework of the structuralist view of theories.[2] In the next one we shall try to show how these issues can be tackled with such a notion.

»When philosophers discuss laws of nature they speak in terms of universality and necessity«, writes van Fraassen (1989), one of the most prominent exponents of the semanticist family, to which the structuralist view also belongs. The two arguments presented above against the existence of biological laws refer precisely to the lack of universality and necessity of the candidates. As we have seen, however, with these criteria not only biological laws but also the usually more respected physical laws should be rejected as such. In fact, due to the lack of unproblematic criteria for lawlikeness, van Fraassen (1989) proposes that we give up the category of a law of nature altogether. His criticism of the concepts of a natural law and of nomic necessity (see also van Fraassen 1977) and his skeptical attitude towards them is shared by other authors, for instance Swartz (1995). This skeptical attitude, however, does not imply that there are no fundamental equations or basic principles of theories which organize actual scientific practice, but rather that these equations are conceived not as *laws of nature*[3] but as *scientific laws* (Swartz 1995) or *laws of the models* (van Fraassen 1989, 1993). Such laws are

[2] See Balzer, Moulines, Sneed 1987 for a complete exposition, or Díez, Lorenzano 2002 for a brief presentation of this metatheoretic conception.

[3] See Weinert 1995 for a discussion of the concept of a law of nature.



not regarded as empirical regularities governing the natural world independently of whether intelligent beings possess knowledge of their truth and necessity or of whether an appropriate symbolic representation for some of those regularities has been developed; instead, they are taken as human creations. Laws, on this view, refer to those regularities of the natural world (or better of the *modeled world*) that are known to us and that are represented in the appropriate symbolic form in a collective effort to explain, predict and control parts of the world. Henceforward when we mention laws we shall refer always to laws of science, in particular to laws of biology or of biological science.

However, despite sustained efforts, we still don't have a satisfactory concept of a scientific law at hand, i. e. we still lack an adequate set of necessary and sufficient conditions serving as criteria for a statement to be considered a »(scientific) law«.[4] Worse still, »[i]t is likely that no such set of conditions can ever be found that would appear satisfactory to everybody since the notion of a law is a strongly historical, discipline-dependent kind of notion« (Balzer, Moulines, Sneed 1987, 15). Within the structuralist tradition, discussion of the notion of a law (see for instance Balzer 1979a, Balzer, Moulines, Sneed 1987, Bartelborth 1988, Moulines 1978/1982, 1991, Sneed 1971, Stegmüller 1973, 1976, 1978, 1979a, 1979b, 1986) have usually focused on what Stegmüller (1973) called the ›fundamental law of a theory‹.[5] And when the criteria for a statement to be a fundamental law are discussed, there is a tendency to speak about »necessary conditions« (Stegmüller 1986), »*weak* necessary conditions« (Balzer, Moulines, Sneed 1987) or about »›symptoms‹, some of them even formalizable« (Moulines 1991), although it is admitted that »in every particular case of reconstruction of a given theory, as

[4] See Stegmüller 1983 and Salmon 1989 for an analysis of the difficulties of the classical explication of the notion of scientific law.

[5] The expressions ›fundamental law‹ and ›special law‹ are not used here in Fodor's sense (Fodor 1974, 1991) – the former for laws of basic or fundamental sciences, the latter for laws of special sciences – but rather in the sense used by structuralists, i. e. for different kinds of laws within a theory. Nor, as will be seen below, is ›fundamental law‹ used in the sense of the classical explication mentioned in section 2. Besides, it should be mentioned that what Stegmüller (1973) calls the ›fundamental law of the theory‹ is the ›fundamental set-theoretical predicate‹, the extension of which is the totality of the theory models, characterized by the totality of the definitional conditions (or »axioms«) of such a predicate. These axioms are not only the ones that identify the logical and mathematical type of the models by way of characterizations or typifications, called ›improper axioms‹, but also those that impose additional, not merely logical restrictions, called ›proper axioms‹. The treatment of laws is later modified, the change becoming specially clear after Balzer, Sneed 1977/1978, where the former *core* of Sneed 1971 and Stegmüller 1973 – one of whose identifying elements is the central, basic, or fundamental law(s) – comes to be conceived as the basic theory-core corresponding to the basic theory-element of a theory-net. The expression ›fundamental law(s)‹ comes to refer to the proper axiom(s) of the theory-core of the basic theory-element. (For these notions see the references mentioned in note 2.)

a general rule, it seems to be relatively easy to agree, on the basis of informal or semiformal considerations (for example, on its systematizing role or its quasi-vacuous character), that a certain statement should be considered as a fundamental law of the theory in question« (Moulines 1991, 233).

Stegmüller (1986) mentions two criteria as necessary conditions for something to qualify as a fundamental law: first, having a cluster or synoptic character and, second, being valid in every intended application of the theory. The first criterion, having a cluster or synoptic character, which made its first appearance in the structuralist literature in Stegmüller 1979a, 1979b, and which is further discussed in Balzer, Moulines, Sneed 1987 and in Moulines 1991, has received different formulations, some more demanding than others. According to the most demanding of them, »any correct formulation of the law should include necessarily *all* the relational terms (and implicitly also all the basic sets) and, therefore, at the end, *every fundamental concept* that characterize such a theory« (Moulines 1991, 34). However, when phrased in this way, this feature, as Moulines himself recognizes (Moulines 1991, 233–234), is not possessed by all possible candidates of fundamental laws; noteworthy exceptions include the fundamental laws of continuum mechanics and of electrodynamics, which, according to the analysis made by Bartelborth (1988, 19ff., 45f., 53), »do not seem to be apt to be reformulated as synoptic laws in a plausible and natural way« (Moulines 1991, 234). However, the feature is possessed by a great number of fundamental laws, so that it is a »frequent symptom« (Moulines 1991, 235).

Weaker formulations of this criterion do not require that all the fundamental concepts occur in every fundamental law, but only that »several of the magnitudes« (Stegmüller 1986, 23), »diverse functions« (Stegmüller 1986, 93), »possibly many theoretical and non-theoretical concepts« (Stegmüller 1986, 386), »almost all« (Balzer, Moulines and Sneed 1987, 9) or »at least two« (Stegmüller 1986, 151) do. According to these versions some propositions are fundamental laws that were excluded by the stronger formulation of the criterion and that probably should have been taken as laws, setting them apart from »mere« characterizations such as those mentioned in the previous note (and also from possible special laws), in which the terms occur in isolation.[6]

The second criterion for a statement to be a fundamental law, though implicit in many structuralist writings, has been explicitly introduced by Stegmüller (1986). This criterion posits that a sentence must possess »validity in *every* intended application« (Stegmüller 1986, 93). This criterion allows us to distinguish between

6 It should be clear that in thinking about this criterion one must bear in mind that (in all its versions) the criterion is strongly dependent on the language used, i. e. on the formulation of the theory, since it is only in relation to a theory that a term can be considered to be primitive, basic, or fundamental.



fundamental laws and special laws, which, though synoptic, are only valid in some but not in all applications of the theory.[7]

Moulines (1991) emphasizes two further »symptoms« of being a law: the systematizing role of laws and their quasi-vacuous character. Fundamental laws are (empirically) quasi-vacuous in that they are highly abstract, schematic, and contain essential occurrences of $T$-theoretical terms so that they can resist possible refutations, but which nevertheless acquire specific empirical content through a non-deductive process known as ›specialization‹. This process, which provides more specific laws (the so-called ›special laws‹),[8] consists in the introduction of further restrictions, or specifications of (some of the components of) the fundamental law(s), in such a way that they become progressively concrete in diverse directions until we finally obtain the so-called ›terminal specializations‹ in which all components are specified.[9]

The quasi-vacuous character of the fundamental laws has led some authors to doubt their empirical nature and to propose to regard them as »non-empirical«, »analytic«, »a priori«, »tautological stipulations«, »mere conventions«, or »mere definitions« of at least some of the $T$-theoretical terms included. In this vein, Moulines proposes to call this type of statements ›empirically unrestricted‹ (Moulines 1978/1982, 96): on the one hand they are irrefutable or empirically vacuous, but on the other hand they are different from the paradigmatic examples

7 In a recent article, Falguera (2004) proposes to consider a criterion that allows to »discriminate among the more basic laws of a theory, which are fundamental laws« (Falguera 2004, 16), one which makes use of »elements [...] that have been present but not explicit for the structuralist literature (and in some degree for Kuhn)« (Falguera 2004, 15), that connects the character of fundamental law with the pragmatic (»informal«, »global« or »strong«) criterion of $T$-theoreticity of the structuralist conception. In particular, Falguera reverses the usual relation – where the notion of a fundamental law is used (given the presupposition of, or the existence of at least, one successful application or an actual model of $T$) to identify $T$-theoretical terms – with the intention of characterizing the notion of a fundamental law with the concept of theoreticity. Thus »a law is fundamental for a complex mature theory (at a given time) if and only if there is at least one concept of the theory whose determination requires always ultimately that the law in question is adequate for at least one application« (Falguera 2004, 15–16). This criterion seems to be a variant of (or perhaps a way of making more precise) the second of the criteria mentioned by Stegmüller, although it differs from it in its biconditional form, that is, it is assumed that it provides both necessary and sufficient conditions for a law to be considered fundamental.

8 The fact should be emphasized that, in contrast to the classical analysis, the relation between the more general, (fundamental) and the more specific laws is not one of deduction but one of specialization. The latter are called ›special laws‹ instead of ›derived laws‹.

9 In case the specifications introduced turn out to be adequate the intended applications become »successful« ones. Whereas in general it is through the »empirical claims« associated with the various theory-elements that form a theory-net that a connection between the »semantic« or »model-theoretic« and the »classical« (»syntactic« or »statement«) view can be established. The empirical claims associated with the *terminal* special laws are the ones that can be subjected to the traditional analysis of hypothesis testing and evaluation.

of analytic statements such as »all bachelors are not married«. These statements are irrefutable or empirically vacuous, since their structure is such that, if no further restrictions are considered, *any* empirical system – formulated in the non-theoretical vocabulary (pretheoretical, antecedently available or independent) of the theory – can be trivially »extended« or »completed« – by way of the addition of the $T$-theoretical terms – until it is transformed into a full (theoretical) model of the theory in question, hence satisfying its fundamental law(s). In addition, they are distinct from statements traditionally considered analytic. Because although there is a close relation between $T$-theoretical terms and the fundamental laws which introduce them – that is, their extensions can only be determined by logically presupposing the validity of the laws –, these do not »define«[10] the $T$-theoretical terms strictly, since they violate the criteria of eliminability and non-creativity that (»explicit« or »logical«) definitions must satisfy.[11]

Owing to this peculiar character of fundamental laws, it has also been suggested to consider them as a special kind of »quasi-analytic« or »synthetic a priori« statements. Jaramillo (2004) has recently stressed that it is not alien to, nor new in, the structuralist metatheory to introduce certain Kantian topics, and to use terminology introduced by Kant. This is encountered for example in the identification of the structural core as an »a priori temporally relativized« component, and in the explication of the notion of a presupposition of Sneed's theoreticity criterion »in the analytic-transcendental sense« carried out by Stegmüller (1973) or in the investigation of the »a priori character« of the concepts of space, time, and space-time in contemporary physics carried out by Balzer (1981) or in Moulines' pointing out the concept of force and of Newton's second law as the »conditions of possibility of all mechanics« (Moulines 1987/1982). More recently, Jaramillo (2004) and Falguera (2004) have also linked the notion of fundamental law or guiding principle with the notion of a relativized a priori. The former mentions the notion as present in some followers of Kant. Cassirer is a case in point. The latter alludes to the notion first proposed by Reichenbach (1920), more recently taken up and developed by Friedman (1993, 1994, 1997, 2000, 2002, 2004) and mentioned by Kuhn (1993). Cassirer (1910) having in mind the Kantian distinction between *constitutive* and *regulative* a priori principles, proposes to replace Kant's constitutive a priori with a purely regulative ideal. For Reichenbach (1920), on the other side – according to whom Kant used the expression ›a priori‹ in two very different senses: »First it means ›apodictically valid‹, ›valid for all time‹, and secondly, ›constituting the concept of object‹« (Reichenbach 1920, 238) – the lesson to be learned, later rejected mainly under Moritz Schlick's influence, out of the theory of relativity is that the first sense must be abandoned and the second one retained (Coffa 1991, ch. 10). Reichenbach thus refuses to accept the idea of a priori synthetic judgments, in which the a priori is absolutely fixed and not revisable, incorporated once and for all in our fundamental cognitive abilities, but he does accept a relativized and dynamic version, in which it changes together with the development of the principles of the mathematical and physical sciences themselves, keeping the characteristically Kantian constitutive function of structuring and framing natural empirical knowledge by means of those principles, thus making it possible. Kuhn, on the other hand – in a line of thought that is very close (and with mutual influences) to that of the structuralist view, as not only structuralists (Sneed, Stegmüller and Moulines), but also Kuhn himself (Kuhn 1976, 1977, 1981, 1983a, 1989, 1990, 1992, 1993, 2000) have pointed out – identifies the »symbolic generalizations« as one of the essential components of paradigms or disciplinary matrices (Kuhn 1962/1970, 1974a, 1979, 1981). These are the formal or the readily formalizable components of the paradigms/disciplinary matrices, and are ›generalization-sketches‹ (Kuhn 1974a), ›schematic forms‹ (Kuhn 1974a), ›law sketches‹ (Kuhn 1962/1970, 1970, 1974a, 1974b, 1983a), ›law-schema‹ (Kuhn 1962/1970) that establish the more general relations between the entities which inhabit the field under investigation and are not questioned in the long period of normal science, in which scientists carry out researches under the paradigm-disciplinary matrix by solving puzzles. The concrete successful solutions to the puzzles, the *shared examples* or *exemplars*, are obtained by adapting the symbolic generalizations in order to get the specific symbolic forms required for the solution of a particular problem. Symbolic generalizations, which Kuhn shall later call ›nomic generalizations‹ or simply ›laws‹, and that »according to Stegmüller's analysis [...] are nothing but the *fundamental laws* of the so-called ›structural core‹ of a theory« (Moulines 1978/1982, 89) – seem to possess characteristics both of analytic and synthetic statements: analytic inasmuch as they »function [...] in

10 Except in the sense that usually (since Schick 1918) is associated to the modifier »implicitly«, or in which sometimes one talks of »physical« or »operational definition«, making reference to the determination of the extension – measurement – of such terms (see, e. g. Balzer 1979b).

11 Moulines (1978/1982) tries to account for the quasi vacuous character of fundamental laws, as well as for their being empirically unrestricted, through the analysis of their logical form. This can be seen as a complement of the analysis of the synoptic character of laws. Taking as a basis the examples of Newton's Second Law – the fundamental law of classical particle mechanics – and the fundamental law of the thermodynamics of simple systems, Moulines points out two common characteristics: (1) the presence of existential quantifiers, and (2) the presence among the $T$-theoretical terms of at least one function of functions or »functional« (not simply a function), which makes it necessary to introduce a second order existential quantification on it (or them). Fundamental laws with these two characteristics are called by Moulines »guiding principles«. However, not every fundamental law is a »guiding principle« in this sense. There are fundamental laws with other logical forms, as well as with theoretical terms that are simply functions and not functionals, such as the law of conservation of momentum, the fundamental law of classical collision mechanics, at least up to 1685, when it is incorporated into classical Newtonian mechanics (see next footnote). On the other hand, this analysis of guiding principles in terms of their logical form needs to come to terms with the problem of the existence of logical equivalents, i. e. statements that are logically equivalent with the chosen formulations of the guiding principles but have a different logical form, besides being, as is obvious, relative to the logic being used.

part as definitions of some of the symbols they deploy« (Kuhn 1962/1970, 83) and that »no amount of observation could refute« (Kuhn 1962/1970, p. 78) and synthetic in that »they function in part as laws [of nature or empirical]« (Kuhn 1962/1970, 183), that »[none of] the member terms of an interrelated set [...] is independently available for use in a definition of the other« (Kuhn 1983b, 567) and that they »can be tested [through the insertion of specific values]« (Kuhn 1983b, 567). Besides, these generalizations are »constitutive« *of the theories* to which they belong (Kuhn 1976, 189) and are »necessary« *in that context* (Kuhn 1983b, 566–567; Kuhn 1989, 22 n. 19; 1990, 317 n. 17), in contrast to symbolic forms or specific laws that are not constitutive of the theories in which they appear and are »all of them contingent« (Kuhn 1983b, 566). That symbolic generalizations seem to possess features of analytic as well as of synthetic statements, together with their constitutive and necessary character, is what later moves Kuhn to characterize them as »quasi-analytic« (Kuhn 1974a, 304 n. 14; 1976, 198 n. 9) and finally, as »synthetic a priori« (Kuhn 1989, 22 n. 19; 1990, 317 n. 17). The same characterization can be applied to the fundamental laws of the structuralist view.[12]

[12] Falguera (2004) considers it unsatisfactory to present the law of conservation of momentum as the most basic or fundamental law of collision mechanics since, as is well known, this theory – first conceived by Descartes (in his posthumous treatise *Le monde ou Traité de la lumière*); the really correct version was given by Huygens in the second half of the $16^{th}$ century – although it enjoyed autonomous life before 1685, ended up being incorporated into Newtonian mechanics. Thus the term ›mass‹, which was until that date *collision-mechanics*-theoretical according to the pragmatic or »global« criterion of *T*-theoreticity of the structuralist view, came to be *Newtonian-mechanics*-theoretical (for a structuralist analysis of this »incorporation« in terms of the reduction of collision mechanics to classical particle mechanics, see Balzer, Moulines, Sneed 1987, 255–267). According to Falguera, by considering the law of conservation of momentum as a fundamental law of collision mechanics, Moulines »practically suggests that in each theory-net that we can isolate, disregarding whether it may be part of a more complex net, we can identify a fundamental law [...] [which] obviously [...] constitutes a trivialization of the notion of fundamental law which does not correspond with the synthetic *a priori* of Kuhn, Reichenbach, and Friedman and their constitutive role« (Falguera 2004, 13–14). We shall not assume here that this situation represents any »trivialization of the notion fundamental law«, but rather that it recalls the dependence of lawhood on historic and pragmatic aspects (as well as the informal notion of *T*-theoreticity): the law of conservation of momentum was undoubtedly the fundamental law of collision mechanics from its appearance until it was incorporated into Newtonian mechanics, but afterward it could be seen (Moulines 1978/1982, 104, makes an analogous suggestion concerning the guiding principle of the thermodynamics of simple systems with respect to the guiding principle of reversible thermodynamics) as a fundamental sub-law with respect to Newton's Second Law, or it could be considered as a fundamental law when collision mechanics is considered by itself, disregarding its connection with Newtonian mechanics (this criterion could be maintained even if Falguera's proposal regarding the notion of fundamental law is retained, although based in the *formal*, local or weak criterion of *T*-theoreticity of the structuralist view: a term *t* is non-theoretical in the theory *T* if there exists no *T*-admissible method for the determination of that term, i. e. if there is no way of determining its extension by means of *T* or employing *T*; conversely, a term *t* is *T*-theoretical if there is a *T*-admissible method of determination for *t*; concerning this criterion of *T*-theoreticity, see Balzer, Moulines, Sneed 1987, ch. 2, Gähde



The other »symptom« mentioned by Moulines, the systematizing role of the fundamental laws, might be understood as one that makes it possible to include diverse applications within the same theory because it provides a guide to and a conceptual frame for the formulation of other laws (the so-called ›special laws‹), which, as we have seen above, are introduced to impose restrictions on the fundamental laws and thus apply to particular empirical systems. Due to the process of »specialization«, which construes theories in a strongly hierarchic way, and the obtaining of »successful« applications, it is possible to integrate the different empirical systems, »models« or »exemplars« under the same conceptualization, in which the fundamental law(s) occupy a central position. But, insofar as the fundamental laws, on the one hand, are quasi-vacuous, telling us that certain relations between their components obtain, but leaving those components indeterminate until the pertinent specializations are carried out, and on the other hand function heuristically as guides or rules for the formulation of increasingly restrictive special laws, as principles they seem to possess a merely *regulative* rather than a *constitutive* character (Kant 1781/1787, A 180/B 223) and in that sense seem to fit Cassirer's line of thought (1910). Due to this regulative character, fundamental laws determine to a great extent some of the actions scientists carry out in their practice. In particular, as we have pointed out, specialization, but also others closely related to it and traditionally recognized by philosophers of science, such as testing hypotheses and explanation.

But let us now take a look at how this notion of fundamental law relates to universality, necessity and a priori character of laws of biology discussed in previous sections.

## 7. Universality, necessity and aprioricity of the laws of biology

We shall first consider the *universality* condition. For the structuralist view, as well as for other members of the semanticist family, it is not necessary that the fundamental laws of a theory have an unlimited scope, be applicable at every time and place and have as a universe of discourse something like »one big application« that constitutes one single or »cosmic« model (Stegmüller 1979b, Mosterín 1984). In fact, only the fundamental laws of some cosmological theories, applicable to the cosmic model, and the laws of the »Great Unified Theory« (GUT), if

1983, 1990, and Balzer 1985, 1986). Something similar would happen with the »synthetic *a priori* of Kuhn, Reichenbach, and Friedman and their constitutive role«; one has to bear in mind that they don't play that role in any absolute sense, but rather that they are a relativized a priori, and play their role as such. In particular, they play their role not atemporally nor independently of the body of knowledge considered.

existent, are universal in this sense. However, this is not the standard situation. The laws of physics normally apply to partial, well bounded physical systems (the set of intended applications), and not to the cosmic model.[13] The same is true of the laws of biological sciences. The majority of scientific theories (including the biological ones) have differing degrees of generality within the same conceptual frame. Usually there is a single fundamental law »at the summit« of the hierarchy – not valid for all time and place, but rather in all models of the theory, and that is supposed valid for all its intended applications – and a group of more special laws – that apply to a more restricted domain – with differing degrees of »concreteness«, »specification« or »specialization«.

Regarding *necessity*, it could be maintained that the notion of fundamental law is neutral with respect to the dispute about the nature of laws – as far as I know the structuralist literature has not dealt with this point – and is thus compatible with different ways of analyzing the concepts of accidentality and of natural or nomic necessity. In particular – and along the lines set above, that is, restricting our analysis to scientific laws, and also in agreement to Kuhn's above mentioned considerations – it is also compatible with the stand of those who maintain that the notion of necessity, when used at all, is not used for assigning natural necessity, but rather – and following also van Fraassen (1977, 1989, 1993) and Swartz (1995) – (at most) *necessity of the models* determined by the fundamental laws. In this sense, the fundamental laws of biological theories should be considered *necessary in their domain of application*, even if outside that domain – which includes (the conceptualization of) the processes which originated the empirical systems it comprises – it need not be so.

This aspect is closely related to the non-empirical or a priori character of (at least some of the) biological laws according to the analyses of section 4. In our view, this character could best be conceived of as »quasi-vacuous« or »empirically unrestricted« in the above mentioned sense, rather than »non-empirical«. The fundamental laws of biology then share this character with the fundamental laws of other disciplines such as physics. Hence we also claim that, if the terminology honored by philosophical tradition is to be kept in use, it is more adequate to consider them as synthetic a priori statements, but in the sense of an a priori *relativized to the theories* in which the laws are fundamental, instead of »analytic« or »a priori« understood as opposed to empirical. The »non-empirical« or »a priori« character that the authors mentioned in that section believe to detect seems to derive from the fact that they consider fundamental laws independently of their application, i. e. independently of the evaluation of their empirical adjustment to

[13] As Toulmin emphasized in 1953: »Any one branch of physics, and more particularly any one theory or law, has only a limited scope: that is to say, only a limited range of phenomena can be explained using that theory, and a great deal of what a physicist must learn in the course of his training is concerned with the scopes of different theories and laws« (Toulmin 1953, 31).



the systems to which they are expected to apply. Thus it is supposed that in case the conditions or restrictions they prescribe are satisfied, the relation they establish will hold in a series of systems, but it is not yet determined in which empirical system in particular they are actually satisfied: in the »theory« or in the »mathematical model« they »work well«, they are »true«; it only remains to be found out whether (a parcel of) the »world« (and which parcel) behaves accordingly, i. e. whether (and where) they apply successfully. Besides, not all laws mentioned by these authors can be seen as the fundamental laws of the theories in which they appear. Those that are not (like the Hardy-Weinberg law, as we would say, following van Fraassen 1987)[14] should be considered as special laws and hence not as »quasi-vacuous« or »empirically unrestricted« or as »synthetic a priori«. However, we shall not delve here in the study of the examples they present, which would in addition need a clear identification of the theories in which the laws appear. Instead, we shall see how the law of matching, made explicit in the reconstruction of classical *genetics*, adjusts to the notion of fundamental law discussed in the previous section.

## 8. The fundamental law of classical genetics

Bearing in mind what has been said about fundamental laws, we would like to comment on a point in which we disagree with Smart as well as with his opponents, Ruse and Munson. All three claim that, if some statement of genetics is to be considered a »law in the strict sense«, it must be one of the so-called ›Mendel's laws‹. Regardless of the questionable attribution to Mendel of the formulation of the laws which were to carry his name (see Lorenzano 1995, 1997, 2002b, 2006), we do not think this is the case. Neither the law of segregation nor the law of independent assortment are schematic and general enough not just to

[14] »The scientific literature on a theory makes it relatively easy to identify and isolate classes of structures to be included in the class of theoretical models. It is on the contrary usually quite hard to find laws which could be used as axioms for the theory as a whole. Apparent laws which frequently appear are often partial descriptions of special subclasses of models, their generalization being left vague and often shading off into logical vacuity. Let me give two examples. The first is from quantum mechanics: Schrödinger's equation. This is perhaps its best known and most pervasively employed law – but it cannot very well be an axiom of the theory since it holds only for conservative systems. If we look into the general case, we find that we can prove the equation to hold, for some constant Hamiltonian, under certain conditions – but this is a metamathematical fact, hence empirically vacuous. The second is the Hardy-Weinberg law in population genetics. Again, it appears in any foundational discussion of the subject. But it could hardly be an axiom of the theory, since it holds only under certain special conditions. If we look into the general case, we find a logical fact: that certain assumptions imply that it describes an equilibrium which can be reached in a single generation, and maintained. The assumptions are very special, and more complex variants of the law can be deduced for more realistic assumptions – in an open and indefinite sequence of sophistications« (Van Fraassen 1987, 110).

connect all or almost all of the terms of the theory but also to be accepted by the scientific community of the geneticists as valid for all applications and as providing a conceptual frame adequate to formulate all the special laws of classical genetics. These laws therefore cannot be considered fundamental laws of genetics. Even worse for those who assume that there is at least one fundamental law of genetics, geneticists have not formulated such a law. That is to say no such law can be »observed«[15] in the literature of genetics.

Nevertheless, on the other hand, the reconstruction of classical genetics carried out within the framework of the structuralist view of theories (Balzer, Dawe 1990, Balzer, Lorenzano 1997 and Lorenzano 1995, 2000, 2002a) suggests the existence of a fundamental law of genetics for systematic reasons, making explicit what was merely implicit.

Classical genetics is a theory about hereditary transmission, in which the transmission of several traits, characters or characteristics (phenotype) is followed from generation to generation of individuals. Ratios (relative frequencies) describing the distribution of those traits are determined, and adequate types and numbers of factors or genes (genotype) are postulated which account for those distributions. The fundamental law determines the ways in which these distributions are »accounted for«, stating that, given two parents – with certain characteristics (phenotype) and genes (genotype) along with a certain relation between characteristics (phenotype) and genes (genotype) – that cross and produce progeny – possessing certain characteristics (phenotype) with certain numbers of genes (genotype), with certain relation between characteristics (phenotype) and genes (genotype) – a certain fit or match (either exact – ideal – or approximate) takes place[16] between the distribution of the characteristics (relative frequencies) and the distribution of genes postulated theoretically (expected or theoretical probabilities), given certain relations between genes and characteristics (of expression of genes from various degrees of dominance or epistasis). This law, which we shall call ›law of matching‹ for want of a better name, even though it is not stated explicitly in genetic literature, underlies implicitly the usual formulations of the theory, systematizing it, making sense of geneticists' practice, and unifying the different heterogeneous models under a single theory. Those models can be conceived as structures of the following type $\langle J, P, G, APP, MAT, DIST, DET, COMB\rangle$ – where $J$ stands for the set of individuals (parents and progeny), $P$ the set of characteristics (or phenotype), $G$ the set of factors or genes (genotype), $APP$ for a function assigning individuals their appearance or phenotype, $MAT$ for a function of crosses that assigns to any pair of parents its progeny, $DIST$ for the relative frequencies of the characteristics observed in the progeny, $DET$ for the relations postulated between genes and characteristics, and $COMB$ for the probability distributions of genes in the progeny, which satisfy the law of matching. More formally expressed, the law establishes that if $x = \langle J, P, G, APP, MAT, DIST, DET, COMB\rangle$, $x$ is a model of classical genetics if and only if for all $i, i' \in J$ such that $MAT$ is defined for $\langle i, i'\rangle$ and for all $\gamma, \gamma' \in G$ such that $DET(\gamma) = APP(i)$ and $DET(\gamma') = APP(i')$ then it is the case that $COMB(\gamma, \gamma') = DIST(DET(\gamma), DET(\gamma'))$.[17]

It is easy to see that in the law of matching we can identify the characteristics or »symptoms« of fundamental laws indicated in the previous section. First, the law of matching can be seen as a *synoptic* law because it establishes a substantial connection between the most important terms of genetics in a »big« formula. It contains all the important terms that occur in genetics, both the *genetics*-theoretical ones (the set of the factors or genes, the distributions of probability of the genes in the progeny and the postulated relations between genes and characteristics) and the *genetics*-non-theoretical ones, which are empirically more accessible (individuals, the set of characteristics, the assignment of characteristics to individuals and of progeny to parental individuals, and the relative frequencies of characteristics observed in the progeny). Second, the law of matching is highly schematic and general and it possesses so little empirical content that it is irrefutable (i.e. it has a »quasi-vacuous« character). Because to examine the empirically determined relative frequency of the characteristics and the theoretically postulated distribution of genes and to set out to test what the law claims – namely: that the coefficients in the distribution of characteristics and of genes in the progeny are (approximately) equal – without introducing any kind of further restrictions, amounts to a »pencil and paper« exercise that does not involve any empirical work. Nevertheless, as we would expect in the case of any fundamental law, despite being irrefutable it provides a conceptual frame in which all special laws can be formulated; that is, special laws with an increasing degree of specificity and with an ever more limited domain of application, until we reach »terminal« specializations whose

15 Authors such as Kitcher (1984) and Darden (1996) agree on this point.

16 Genetics, as virtually all empirical sciences, contains certain approximations. If these are ignored, then the match is *exact*. If these approximations are taken into account, then the match is only *approximate*, but such that the distances between the coefficients that represent a theoretical distribution and those of the relative frequencies do not exceed a given $\varepsilon$.

17 Classical genetics, as well as any other scientific theory, is not an isolated entity, it is rather essentially linked to other theories; in particular, to cell theory, in such a way that factors (or genes) are supposed to be in or on the chromosomes, which are transmitted from the parental generation to the progeny through the sexual cells (or gametes). It is due to that link between genetics and cell theory that, in the usual (linguistic or graphic) presentations of the first of the theories, occur terms belonging to the second one, such as ›gametes‹. In order to simplify matters and because of space limitations we do not take into account such links and do not incorporate the gametes as a base set in the structures above introduced nor mention them expressly in the formulation of the law of matching. (For an analysis of the historically changing »interfield connections« between genetics and citology, see Darden 1991; for a structuralist attempt at an analysis of such links, see Casanueva 1997, 1998.)

associated empirical claims can be seen as particular, testable and, eventually, refutable hypotheses.

In addition, it is important to observe that this law has implicitly been *accepted as valid in every application of the theory* because the scientific community has used it as a general background assumption that provides a starting point for the analysis of different distributions of characteristics and serves as *a guide for dealing* with the plethora of empirical situations that geneticists face (systematizing character). So the primary role of the law of matching is to guide the process of specialization, determining the ways in which it must be specified to obtain special laws. According to this law, in order to account for the distributions of the parental characteristics in the progeny, the following parameters have to be specified: a) the number of pairs of genes involved (one or more), b) the way in which the genes are related to the characteristics (complete or incomplete dominance, codominance or epistasis), and c) how the parental genes are distributed in the progeny (with combinations of genes with the same probability or not). When these three types of specifications are made, terminal special laws are obtained, and it is the empirical claims that are associated with these laws that are capable of being subjected to direct empirical tests. In case that these laws »survive« a test, which means that the introduced specifications turn out to be the appropriate ones, one can say that the intended applications have become »successful« and that the empirical systems become »models« of the theory.

In particular, Mendel's Laws, insofar as they impose additional restrictions on the law of matching, thereby adding information that is not already contained in its highly schematic formulation and restricting its area of application (as for example, on having considered only a pair of factors or having considered more than one, but the same probability for any possible combination of parental factors), can be obtained from the fundamental law by specialization and hence must be considered »special laws« of classical genetics even though not as »terminal specializations«.[18]

The presence of all these elements in the law of matching justifies its being considered (on a par with any fundamental law) »synthetic *a priori*«, in the *relativized*, *constitutive* and *regulative* sense studied above.

## 9. Concluding Remarks

In this article we discussed the problem of scientific laws in general and of laws of biology in particular. First, the two main arguments that have been presented against the existence of laws in biology were rehearsed. The first one, due to

[18] For an explicit formulation of the various specializations that comprise the totality of the theory-net of classical genetics, see Lorenzano 1995.



Smart (1963), refers to their *non-universality*; the second one, put forward by Beatty (1995), to their *evolutionary contingency*. Two strategies against those arguments were then presented. One of them submits them to *a critical examination*, either by questioning Smart's analysis of the selected examples (Ruse 1970 and Munson 1975) or by showing that the thesis of evolutionary contingency is not exclusive of biology (Carrier 1995). The second strategy, adopted by authors such as Brandon (1978, 1982, 1997), Sober (1984, 1993, 1997) and Elgin (2003), defends the existence of laws (or principles) in biology – or of statements that, although not fitting the classical explication of the concept of law, play in biology roles that are equivalent to those traditionally assigned to laws – by way of distinguishing two types of generalizations: empirical generalizations – eventually non-universal and contingent, or of limited nomic necessity – and non-empirical or *a priori* ones – that are explanatory and not trivial and even revisable in the light of experience – and affirming that at least some of the more fundamental biological laws or principles belong to the second group, i. e. are non-empirical or *a priori*. Then the concept of a fundamental law proposed within the framework of the *structuralist view of theories* was revised, pointing out four necessary conditions or »symptoms« a statement must satisfy in order to be considered a fundamental law of a theory: 1) having a cluster or synoptic character, 2) being valid in all intended applications, 3) being quasi-vacuous (empirically unrestricted or synthetic a priori) and 4) playing a systematizing role. Then the attempt was made to show how the *discussion* in the philosophy of biology *about the existence of laws* of the discipline and articulated around the issues of universality, necessity, and a priori character of such laws, can be *tackled by means of the proposed explication* of the notion of a fundamental law. Finally, what could be considered *the fundamental law of classical genetics* was identified: *the law of matching*, which satisfies all the conditions required by the structuralist explication of the concept.

To conclude, we wish to mention that the possibility of identifying fundamental laws in biology need not be restricted to classical genetics. This conclusion seems to be suggested by the discussions about the principle of natural selection which resemble the discussions about Newton's Second Law – whether it is an empirical statement or a definition, i. e. an analytic statement, therefore irrefutable. In particular certain informal considerations made about these discussions by authors such as Brandon (1978, 1997) with respect to the theory of evolution by natural selection are relevant here. On the other hand, as we have already mentioned, the Hardy-Weinberg law can hardly be considered a fundamental law of population genetics, but should rather be considered a special law (comparable to another equilibrium, or »zero-force«, law: the principle of inertia in classical mechanics). Population genetics is still awaiting the formulation of a fundamental law that can play a similar role as Newton's Second Law or as the law of matching in the respective theories. However, only the detailed analysis of these and other biological theories will enable us to decide whether they are cases analogous to the one discussed in this paper.[19]

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[19] For the case of population genetics and the theory of evolution by means of natural selection, the attempts of clarification of the structure of those theories undertaken by Beatty (1981), Cadevall i Soler (1988), Ereshefsky (1991), Gould (2002), Hull (1974), Kitcher (1989), Lewontin (1974), Lloyd (1988), Moya (1989), Rosenberg (1985), Ruse (1973), Schaffner (1993), Sintonen (1991), Sober (1984), Thompson (1989), Tuomi (1981), Tuomi & Haukioja (1979) and Williams (1970), among others, could be taken as points of departure.




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