Reduction of biological properties by means of functional sub-types

Christian Sachse

Université de Lausanne
Centre romand de logique, histoire, et philosophie des sciences

christian.sachse@unil.ch

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Reduction of biological properties by means of functional sub-types

Christian Sachse
Université de Lausanne

Abstract:
The general aim of this paper is to propose a reductionist strategy to higher-level property *types*. Starting from a common ground in the philosophy of science, I shall elaborate on possible realizer differences of higher-level property types. Because of the realizer types' causal heterogeneity, an introduction of functional sub-types of higher-level properties will be suggested. Each higher-level functional sub-type corresponds to *one* realizer type. This means that there is the theoretical possibility to reach some kind of type-identity and this opens up the way for theory reduction in a more complete manner. This kind of type-identity will go beyond the common ground of the identity of *tokens* and their reductive explanation. In the second part of the paper, this reductionist strategy will be applied to a specific debate in the philosophy of biology – the reductionist approach to classical genetics from a molecular point of view.

I. The Anti-Reductionist Approach to Special Sciences

Let us take for granted the *supervenience* of higher-level property tokens on configurations of lower-level property tokens and the *realization* of higher-level functional property types by configurations of lower-level property tokens. In addition to that, we assume the *completeness* in causal, nomological and explanatory respects of any lower-level theory with regard to higher-level theories.

As a result of these assumptions, the identity of every causally efficacious higher-level property *token* with its lower-level realizer token is well argued for.[1] So, every token of a functionally defined higher-level property type is in principle reductively explainable by its lower-level realizer token.[2]

Taking this as common ground in the philosophy of science, any anti-reductionist approach to higher-level theories is mainly based on the multiple realization argument (MRA), on an

[1] Compare Kim and the so-called 'supervenience argument' (1998, 38-47).
[2] Compare Chalmers (1996, 42-51) and Kim (2005, 108-120). This strategy can be traced back to Lewis (1970).

explanatory argument (EA), or on some kind of relatively lawlessness (LA) at higher-level theories. These anti-reductionist arguments will be briefly introduced in the following.

(MRA) – The multiple realization argument:

According to this argument, higher-level property types are in general *not uniformly* realized by one configuration type of lower-level properties. Let's assume that a biological property type B can be realized by the different physical configuration types P_1, P_2 or P_3 ($B \leftrightarrow (P_1 \vee P_2 \vee P_3)$). This means, *no symmetrical* relation of the higher-level property type B with *one* of its lower-level realizer types can be established (like $B \leftrightarrow P_1$). But, a symmetrical correlation between *types* constitutes a necessary condition for their reduction[3] and reductive explanation. Given the multiple realization of higher-level property types, token identity and reductive explanation of tokens is not enough for type reduction and their reductive explanation. Therefore, it seems to be the case that the anti-reductionist could accept on the one hand the token identity without accepting on the other hand a reductionist approach to higher-level property *types* that are *multiply realized*.

(EA) – The explanatory argument:

This argument contains at least two aspects. First, there are higher-level property types of which a lower-level explanation is totally *unimportant.* Second, higher-level theories can explain their property types in a way the lower-level theories are *not able* to do. The explanatory unimportance of lower-level theories is mainly based on an explanatory *sufficiency* of higher-level theories. The non-ability of lower-level theories to explain higher-level property types is mainly based on the MRA and a *relative generality* of higher-level theories. Therefore it seems to be the case that the anti-reductionist approach could accept on the one hand that every higher-level token is through its token identity in principle explainable by lower-level theories. But on the other hand, there are higher-level property *types* that are not explainable in terms of lower-level theories.

(LA) – The lawlessness argument:

There are different aspects of this argument. Let us focus on some kind of relatively lawlessness at higher-level theories. We assume that there *are* laws at higher-level theories but the theories are not that formalized by law-like principles. Therefore, no higher-level

[3] Compare Nagel (1961), chapter 11.

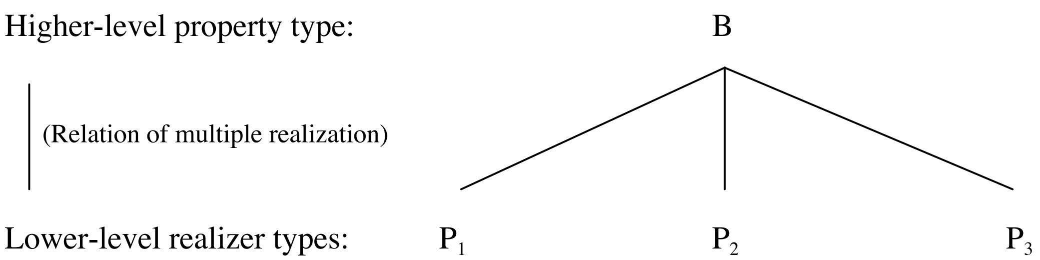
theory can be *representatively* captured by the reduction of all its laws to lower-level laws, or the derivation of all its laws from lower-level laws respectively. Therefore it seems to be the case that the anti-reductionist could accept on the one hand that every higher-level token falls through its token identity under a lower-level law – but on the other hand one can deny a reductionist approach to the higher-level theories mediated by a reductionist approach to higher-level laws.

Now, I would like to query these anti-reductionist arguments for a reductionist point of view.

II. The Fate of any Anti-Reductionist Approach

The fate of MRA depends on the causal features of the realizers. Every higher-level property type is taken to be causally homogenous[4] within a functional definition – that is, to be defined by types of characteristic causes and effects. So, the multiple realization argument can be formulated in the following manner:

> We can subsume higher-level property tokens under *one* functional property type of the higher level because they are causally homogenous (within no interfering environment). That is, they have at least one of the characteristic causes and at least one of the characteristic effects that *define* the functional property type.
>
> But, we *cannot* subsume the appropriate lower-level realizer tokens under one type of the lower level because they are causally heterogeneous (within no interfering environment). That is, they have causes and effects that are characteristic of different lower-level types.
>
> For that reason, a *symmetrical* connection of a multiply realized higher-level type with a lower-level realizer type is *not* possible. This one-to-many relation can be sketched as follows:

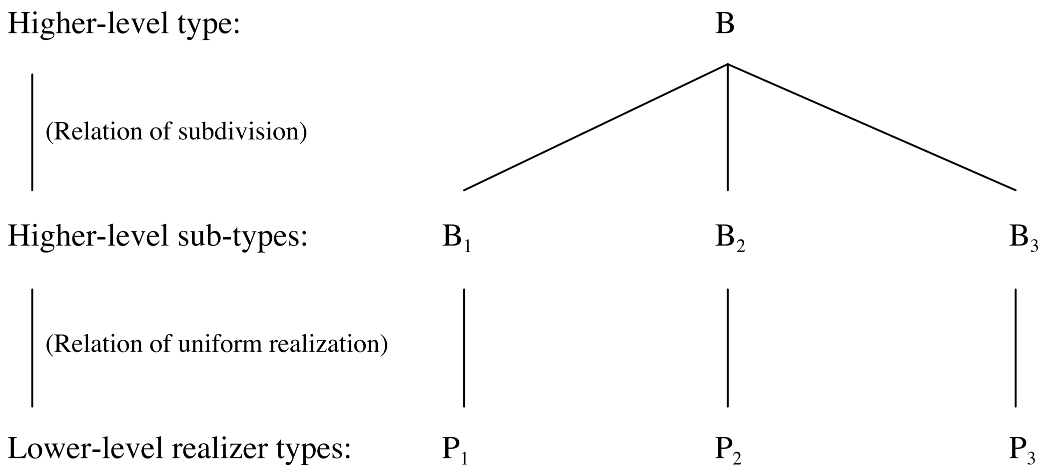


[4] Compare Esfeld (2005).

However, what are the consequences of MRA if the causal heterogeneity of the lower-level realizers will be relevant with regard to the higher-level? That is the case if the different realizer types are *distinguishable* on the higher level. One point of my reductionist strategy is to show that there is no general argument against that possibility of distinction – the other point is to elaborate on its reductionist implications.

The different realizer types are causally heterogeneous. To have a different composition, say of molecules, is in this connection equivalent to be causally heterogeneous – because two different molecular compositions always possess different molecular causal powers. To be causally heterogeneous is to differ with respect to causes and effects. Let us leave aside the causal past despite its importance especially in biological and human sciences. We will focus on the question whether an *environment is possible* in which the different causal effects of the different realizers are relevant with regard to the higher level. It is easily imaginable that there are *always* environments possible in which the different realizer types give rise to different higher-level effects. Therefore, different realizer types possess in certain environments also different functions with respect to the higher level.

Because of these different functions in certain environments, we can introduce appropriate functional sub-types of every multiply realized higher-level property type. These higher-level functional sub-types will correlate only with *one* appropriate type of realizer:



Consequently, each higher-level sub-type (B_1, B_2 or B_3) is uniformly realized (by P_1, P_2 or P_3 respectively).[5] As a result of such an introduction of functional sub-types, we can in principle avoid the anti-reductionist consequences of the multiple realization. For in principle, the

[5] Compare Hooker (1981, part III, in particular 498-507).

higher-level theory can consider the introduction of sub-types and therefore be only about properties that are *not* multiply realized.

The fate of EA depends on an explanatory difference between theories. The anti-reductionist could claim that higher-level functional properties are sufficiently explained by *their* theories and there is no need of *lower-level* explanations. But, how can he argue for that?
There are four points I would like to mention. First, what criterion at the higher-level theories do we have for their explanatory sufficiency that can be taken for an anti-reductionist argument? If there are only arguments based on epistemic advantages, as I see, don't mind the anti-reductionists. We are talking about *possibilities in principle* to reduce or not. Second, because of the relative completeness in causal, nomological and explanatory respects, *no* lower-level theory is in general *unimportant* with regard to properties of higher-level theories. Third, every higher-level theory can in principle consider uniformly realized functional (sub-) types. Therefore, every higher-level functional property type (or sub-type) is in principle through its identity with its realizer type *reductively explainable* in terms of lower-level theories. Fourth, generality might be an epistemic advantage of higher-level theories – but in effect it is nothing more than an *abstraction* of details. This means, there is once again only an epistemic argument to favour higher-level theories over lower-level theories.

The fate of LA depends on the question whether or not the higher-level theory can be sufficiently represented by its law-like principles. But on the contrary, what part of a higher-level theory is *not* represented by law-like principles? Indeed, only non-scientific parts. For that reason, a *scientific* theory has to include at least law-like functional definitions of its concerning properties and its scientific part is represented by law-like principles. As above-mentioned, every higher-level theory can in principle consider functional property (sub-) types that are symmetrically connected with lower-level realizer types. Because of this symmetrical connectability, every higher-level theory can in principle consider law-like principles that are reducible and derivable.

III. The Reduction of Classical Genetics to Molecular Genetics

The relationship between classical and molecular genetics has been the object of much controversy in recent decades. Within this debate in the philosophy of biology, some kind of reductionist consensus is reflected in the approaches of Nagel (1961), Schaffner (1967 and 1969), Goosens (1978), Hooker (1981), Rosenberg (1985, 1994, 2001 and 2005a), Waters

(1994) and Weber (2005a) among others. On the contrary, some kind of anti-reductionist consensus is reflected in the approaches of Hull (1972 and 1979), Kitcher (1984, 1993 and 1999), Kincaid (1990) and Vance (1996) to mention but a few examples.

Let me recap some kind of common ground in this debate – and then apply my reductionist strategy. First, classical property tokens *supervene* on configurations of molecular property tokens. Second, every functionally defined classical property type is *realized* by configurations of molecular property tokens. In addition to this, we assume that molecular genetics is *relatively complete* in causal, nomological and explanatory respects with regard to classical genetics. Therefore, there is a good argument for the identity of tokens. As a result of this, every classical token is in principle reductively explainable in molecular terms. To examine the relationship between classical and molecular genetics in the frame of this paper, let us take the functionally defined classical gene as a representative part of classical genetics. This can be justified by reference to the central importance of the gene concept within classical genetics.

Despite the debate on genocentrism[6], it is obvious that the DNA *without* a certain molecular context cannot realize the functional role we attribute to classical genes. For instance, special enzymes like the RNA polymerases for the transcription or like the DNA polymerases for a replication of the DNA are needed. Without going into detail at this point, let us assume that each type of a classical gene is realized by a certain sequence of DNA *and* a molecular context.[7] Not to limit the molecular context here constitutes no theoretical problem. But, let us assume for the basic purpose of this paper that the classical property of having a certain gene type is realized by a locally limited molecular configuration within an organism.

Applying the concept of functional reduction[8], every classical property type can be functionally defined if a causal relevance is attributed to it. In a simplified form, we can therefore functionally define the property of having a certain classical gene type, say gene X for plant P ($_{type}$geneX), as follows:

Characteristic causes:

The inheritance of the homozygous[9] alleles X_1 and X_2 by the egg cell and the sperm cell respectively from the parental generation causes the existence of gene X in the zygote the

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[6] Compare Rosenberg (2005b) and Weber (2005b).

[7] Compare Waters and the context dependency of his "Molecular Gene Concept" (1994, 178-182).

[8] Compare Kim (2005, 101-102).

[9] In this functional definition, we can assume for simplicity the homozygosity of the two alleles of gene X. Heterozygosity can be functionally defined in an analogous way.

plant P grows out from. During the growth of plant P, the alleles X_1 and X_2 are replicated and transmitted. As a result, every somatic cell of plant P possesses the alleles X_1 and X_2.

Characteristic effects:

Gene X of plant P produces in the environment W_1 the phenotypical effect of yellow blossoms during flowering time.

These yellow blossoms cause a contribution C_1 to the fitness of plant P.

Given this functional definition of gene X, we can search for a molecular configuration that realizes the mentioned function. So, let us define the molecular realizer, say a fictive sequence of DNA plus its molecular context ($_{mr}$geneX), in a simplified manner:

Molecular realization of gene X corresponding to its characteristic causes:

The existence of two identical DNA sequences DNA_{X1} and DNA_{X2} in the egg and sperm cell respectively (of the parental generation) causes through its DNA replication (and other molecular mechanisms) the existence of the identical DNA sequences DNA_{X1} and DNA_{X2} in every somatic cell of plant P (all in principle molecularly describable).

Molecular realization of gene X according to its characteristic effects:

The two identical DNA sequences DNA_{X1} and DNA_{X2} in the somatic cells of plant P in the environment W_1 cause through its protein synthesis and the functionality of the synthesized proteins a constitution of the blossom cells to the effect that the light waves are reflected such that they appear as yellow during flowering time.

These light waves reflected by the blossom cells cause the contribution to the fitness of plant P, say for instance, the attraction of insects that causes an increase of the probability of insect pollination (all in principle molecularly describable).

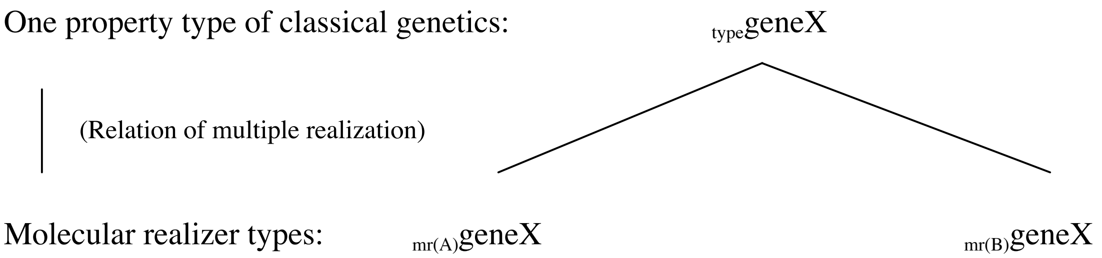
The multiple realization argument (MRA) – applied to gene X:

Given this representative realization of classical gene types, the anti-reductionist can reject a reductionist approach to classical genetics if a multiple realization of gene types can be argued for. Let us have a look at this argument. The above-defined molecular realizer type $_{mr}$geneX satisfies the beforehand-defined functional role of gene X for plant P ($_{type}$geneX). But, the anti-reductionist can argue for molecular realizer types of gene X different from $_{mr}$geneX. It is possible that *different* molecular realizer types fulfil the functional role of gene

X for plant P ($_{type}$geneX). We can consider an extreme position of this multiple realization argument in this context – a difference of only one DNA base between two molecular realizer types. Let us call them $_{mr(A)}$geneX and $_{mr(B)}$geneX:

1. The molecular type $_{mr(A)}$geneX realizes the above-defined functional role of gene X for plant P ($_{type}$geneX).
2. The molecular type $_{mr(B)}$geneX differs with regard to type $_{mr(A)}$geneX in one base of the DNA sequence. But this difference of one DNA base results in no difference as regards the realization of the above-defined functional role of gene X for plant P ($_{type}$geneX). This is possible because DNA differences need not make differences with regard to the synthesis of the same protein. Therefore, $_{mr(B)}$geneX also causes the yellow colour of the blossoms during flowering time etc.[10]

So, we can illustrate the mentioned relation of a multiple realization of the above-defined fictive gene X ($_{type}$geneX) in the following way:



To counter this multiple realization argument and reach some kind of type-identity, we can now elaborate on the possibility in principal to introduce functional sub-types of the gene X. This can be done as follows: Given a different molecular composition of the DNA, there is also a difference in causal powers on the molecular level. Thus, the molecular realizer types $_{mr(A)}$geneX and $_{mr(B)}$geneX causally differ with respect to their molecular environment. This means, they have different molecular causes and effects. Let aside the causal past despite its importance especially with regard to evolution. We can focus on the question whether or not an *environment is possible* in which the different causal effects of the molecular realizers $_{mr(A)}$geneX and $_{mr(B)}$geneX are relevant with regard to the level of classical genetics. Corresponding to the general part of this paper, there is always an environment possible in

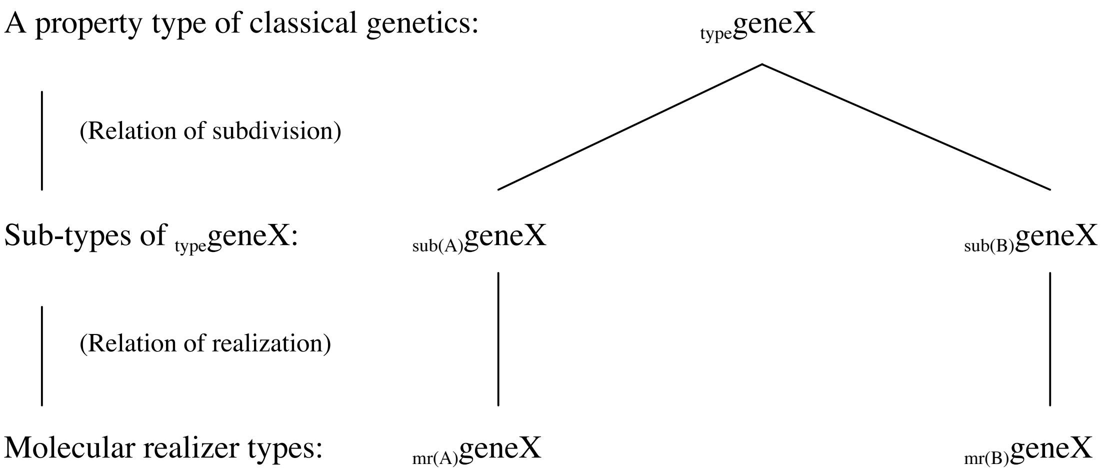
[10] This example of the multiple realization of gene X can be easily established because of the redundancy of the genetic code.

which molecular differences cause different effects on the higher level. Therefore, we can in principle distinguish between different molecular realizers also on the level of classical genetics. For a reductionist purpose, it is in principle possible to introduce functional sub-types of the $_{type}$geneX that *symmetrically* correlate with the molecular realizer types.

We can look into this in more detail. Classical genetics can easily take into account advantages or disadvantages of genes with regard to the fitness of the appropriate organisms. This means, each fitness advantage or disadvantage for plant P can be integrated into the functional definition of the corresponding gene. This enables the aspired introduction of functional sub-types in classical terms. Let's call these sub-types $_{sub(A)}$geneX and $_{sub(B)}$geneX and have a look at possible selective differences for plant P:

1. The functional sub-type $_{sub(A)}$geneX of the above-defined functional type $_{type}$geneX is molecularly realized by $_{mr(A)}$geneX. In addition to the above-mentioned functional definition of type $_{type}$geneX, the first functional sub-type $_{sub(A)}$geneX is also defined by causing a certain resistance probability to ultraviolet light (or a certain resistance against mutations, restriction enzymes, heat …) without losing its function to cause the above-mentioned phenotypical effect of having yellow blossoms during flowering time etc.
2. The functional sub-type $_{sub(B)}$geneX of the above-defined functional type $_{type}$geneX is molecularly realized by $_{mr(B)}$geneX. In addition to the above-mentioned functional definition of type $_{type}$geneX, the second functional sub-type $_{sub(B)}$geneX is defined by causing a certain resistance probability to ultraviolet light (or a certain resistance against mutations, restriction enzymes, heat …) that *differs* from the resistance probability of the first-mentioned functional sub-type $_{sub(A)}$geneX without losing the above-mentioned phenotypical effect of having white blossoms during flowering time etc. This difference causes a *different* selective advantage for plant P.

Therefore, we can illustrate the introduction of the functional sub-types $_{sub(A)}$geneX and $_{sub(B)}$geneX of the above-defined fictive gene X for plant P ($_{type}$geneX) in the following way:



Hence in principle, classical genetics can consider functional sub-types of ${}_{type}$geneX that are *uniformly* realized on the molecular level. Because of this symmetrical correlation, these functional sub-types ${}_{sub(A)}$geneX and ${}_{sub(B)}$geneX are in principle reductively explainable in molecular terms and the appropriate law-like generalizations about them are reducible and derivable. So, classical genetics that considers only uniformly realized (sub-) types is reducible.

But, what can we say about the multiply realized ${}_{type}$geneX that is *not* uniformly explainable in molecular terms and such that its law-like generalizations seem to be *neither* reducible to molecular genetics *nor* derivable from it? There are two points I would like to mention. First, the price of the classical talk about gene types that are molecularly multiply realized is to contain imprecision and vagueness with respect to certain possible environments. In general, if *different* molecular configuration types realize *one* property type of classical genetics the classical tokens bear different selective advantages or disadvantages that are not considered. Second, as mentioned above, classical genetics *can* in principle consider uniformly realized functional sub-types. So, if we want to talk about classical property types that are multiply realized, we abstract from certain functional/selective details. And for doing this, we need no molecular reasons. In other words, there is no question of molecular genetics to explain, reduce or derive multiply realized property types of classical genetics – it is a question *within* classical genetics which talk we prefer.

The explanatory argument (EA) – applied to gene X:

Classical genetics is at least somehow explanatory. This means in the above-examined case, classical genetics is at least able to explain the functional role of the sub-types of gene X for plant P. The anti-reductionist might now claim that the functional sub-types of gene X for plant P are *sufficiently* explained by classical genetics, a molecular explanation would be totally *unimportant* or is *not able* to explain gene X or its sub-types in the right way, etc. Hence, a reductionist approach to classical genetics cannot be based on the explanatory power of molecular genetics.

We can give a concrete counterargument: Despite the above-mentioned necessary subjectivity with regard to an explanatory sufficiency, molecular genetics explains more than classical genetics is able to do. For instance, classical genetics is not able to explain the causal mechanism that is assumed for a certain (sub-)type of gene X with regard to bringing about phenotypical effects like producing white blossoms during flowering time. Or, it cannot explain the causal mechanism the fitness of plant P is based on. On the other hand, molecular genetics is able to explain the causal chain of the realizer of gene X (or its sub-types) – the transcription of the DNA via the translation of the mRNA via the formation of the amino-acid sequence to a protein via the molecular change of the blossom cells as appearing yellow or the molecular description of the insects' attraction respectively. These molecular explanations are independent of classical genetics. Molecular genetics is complete in causal, nomological and explanatory respects with regard to classical genetics. Therefore, it is not possible that properties of classical genetics are for instance causally relevant with regard to properties of molecular genetics without a molecular explanation of this causal influence. But on the other hand, molecular properties can be causally relevant with regard to properties of classical genetics without an explanation within the theory of classical genetics of this molecular influence. So, molecular genetics explains in more detail than classical genetics is able to do. And in principle, the functional definition of gene X (or its sub-types) as a representative scientific part of classical genetics can be explained by molecular genetics.

The lawlessness argument (LA) – applied to classical genetics:

We assume that classical genetics contains at least law-like functional definitions of its properties for being scientific. So, what is the anti-reductionist argument? To claim that classical laws contain more exceptions relative to the laws of molecular genetics? If so, it is only in dispute whether it is possible to reduce classical law-like functional definitions with more exceptions to the molecular laws concerning the appropriate realizers, or to derive law-like functional definitions of classical genetics from laws of molecular genetics.

We can give a counterargument: From a molecular point of view, we can show that it is in principle always possible to express the restricted validity of classical laws by molecular laws. Molecular genetics is able to consider variations in the cells or the environment of plant P in a more appropriate way than classical genetics does. Thus, molecular genetics can express the validity conditions of its laws in more detail than classical genetics is able to do. Therefore, the differences of both genetic theories can be expressed in molecular terms. Take the functional sub-type $_{sub(A)}$geneX that is uniformly realized by the molecular type $_{mr(A)}$geneX. Because of this symmetrical correlation, the laws of classical genetics concerning the functional sub-type $_{sub(A)}$geneX can be compared with the molecular laws concerning the realizer type $_{mr(A)}$geneX. Now it will become clear that the restricted validity of the functional definition of the functional sub-type $_{sub(A)}$geneX results only from the inability of classical genetics to respect or express the conditions of validity in the same way as molecular genetics is able to do. For instance, only molecular genetics can respect the necessary molecular conditions for the transcription of the DNA that lead to the proteins synthesis. Thus, if we neglect these differences with regard to express the validity conditions, there remains no basic argument not to reduce or not to derive respectively laws of classical genetics.

Further anti-reductionist arguments:

Imagine the following scenario: The two functional sub-types ($_{sub(A)}$geneX and $_{sub(B)}$geneX) of the gene X for plant P ($_{type}$geneX) do not differ in their functionality with regard to a certain environment and with regard to a certain time. It is possible that the difference of only one DNA base between the molecular realizers $_{mr(A)}$geneX and $_{mr(B)}$geneX is irrelevant with regard to all current environments of plant P in this world at this time.

So, what can be objected? There is always an environment of some kind and some length of time possible where a difference of only one DNA base causes a functional difference with regard to the fitness of plant P.[11] Such a possibility of environments is sufficient for the possibility in principal to distinguish the different molecular realizers also on the level of classical genetics. Because of this, the introduction of functional sub-types is in principle well argued even if there are no selective differences *within* a certain frame of space and time. The possibility in principle remains.

Furthermore, one may argue that the difference between types and tokens of classical genetics will be lost – something we did not intend to do. Imagine the possibility that there are no single molecular realizer tokens of gene X that do not molecularly differ. These realizer differences lead to the possibility to distinguish them. So in principle, we can introduce

[11] Compare Rosenberg (1994, 32).

functional sub-types on the level of classical genetics according to every molecular realizer token. Because of this, there would be as much classical tokens as classical sub-types. Such an introduction of functional sub-types in classical genetics would make unnecessary the talk of property (sub-)*types* in favour of property *tokens*.

So, what can we do to save a talk of types? If we can argue for a subsumption of at least some molecular tokens of all tokens that realize the gene X for plant P ($_{type}$geneX) under a certain molecular type, there will be a difference between types and tokens on the level of classical genetics as well. The question is whether or not there are good criteria for an individuation of types – on whatever level. A multiple realization of the gene is only given if the realizer differences cause differences within the molecular mechanisms that realize the mentioned function of the gene. In addition to that, the point of my reductionist strategy by means of introducing functional sub-types is essentially to formulate a basic refutation of the multiple realization argument. For instance, the difference of one base at the DNA could be ignored on the molecular level *with respect to a certain molecular environment and with respect to a certain frame of fitness differences*. Consequently, classical genetics can describe, explain and predict its concerning properties and their causal connections as it has done since Gregor Mendel. But we have to keep in mind that there is an ability in principal to introduce functional sub-types. And as a result of this, there is always some vagueness and imprecision in the talk of types with respect to descriptions, explanations and predictions if the types in question are *multiply* realized.

Summary of the reductionist approach to classical genetics:

Because of the representative function of the gene within the theory of classical genetics, a reductionist or molecular approach to classical genetics seems to be well argued for. Given my claimed possibility in principle to introduce functional sub-types on the level of classical genetics and given the principal explanatory power of molecular genetics, the mentioned anti-reductionist arguments can be refuted. As a result of this, a reduction of classical genetics to molecular genetics seems to be feasible.

IV. General Reductionist Consequences

Because of the completeness in causal, nomological and explanatory respects of every lower-level theory, the supervenience of higher-level properties on configurations of lower-level properties, the causal argument for a cross-level token identity and the reductive explanation of higher-level tokens, a reductionist approach to higher-level theories is in general well argued. But, a reductionist approach in a more complete manner faces mainly the objection of the multiple realization argument.

As proposed in this paper, different realizers lead to functional differences on higher-levels. For that reason, the argument of the multiple realization can be refuted by an in principle possible introduction of functional sub-types on the appropriate level. In addition to that, a general objection to the anti-reductionist argument of a relatively lawlessness of higher-level theories and the anti-reductionist explanatory argument has been suggested – and applied to genetics.

So, what are the consequences? The way for a reductionist approach to higher-level theories in a complete manner – to their properties tokens *and types*, and thus to their laws and explanations – is in principle open and reasonable.

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