IS THE "BIOLOGICAL" REDUCIBLE TO THE "PHYSICAL" ?

An Overall Critical Analysis of the Concept of Reduction

in Biology

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Yaman Örs

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We certify that this dissertation is satisfactory for the award of the degree of Doctor of Philosophy.

Prof. Dr. Teo GRÜNBERG

(Supervisor)

Prof. Dr. Ahmet İNAM

(Member of Examining Committee)

Prof. Dr. Cemil AKDOĞAN

(Member of Examining Committee)

Prof. Dr. Fuat A. GÖKSEL

(Member of Examining Committee)

Prof. Dr. Aykut KENCE

(Member of Examining Committee)

Certified that this dissertation conforms to the formal standards of the Institute of Social Sciences.

Assoc. Prof. Dr. Sabri KOÇ

(Director of the Institute
of Social Sciences, METU)

ABSTRACT

Although **reduction in biology or life sciences** as the subject matter of the present essay has been more and more attracting the attention of the philosophers of science for the past few decades, the term "reduction" has been used for various logico-semantical operations and for epistemological purposes in different domains of philosophy. The common point in all these appears to be an attempt to give a simpler and seemingly more basic semantical account of a rather complex construction, be it the terms of a syllogism or the sets of natural numbers, the structure of molecules and molecular phenomena or the psychological processes. In philosophically technical terms, all these operations may be said to share the application of the principle of conceptual economy or Occam's razor so as to arrive at a more essential level of abstract construction (in symbolic logic or mathematics) or of empirical existence (in sciences). This seems to be quite in keeping with one of the apparently very basic aims of doing philosophy, namely to formulate the possibly simplest conceptual construct that would account for the related more complex abstractions or the appreciably more complex states of affairs.

While the general characteristics of the reductive operation, including theory reduction and its different aspects, form the subject matter of the first Part of this dissertation, Part Two as its core is constituted by an analysis of **the problem of reduction in biology**, with a rather detailed discussion on the levels of organization in the empirical world. <u>Reduction in Genetics</u> is presented and discussed as a case in point within the context of the broader issue of <u>reduction of the biological to the physical</u>; and reduction in biology and, by implication, <u>reductive operation in general terms are considered as partial explanations</u>, the term "partial" in this context signifying a qualitative rather than a quantitative sense. As would be expected, the concepts of emergence, correspondence, causal connection and supervenience are among the main philosophical concepts that are dealt with in this part in relation to **reduction viewed as explanation** at the philosophical-conceptual and/or logico-semantical level of discourse.

Part Three has been devoted to **possible implications** of the essay in connection with certain concepts as they are related to the concepts of reduction and reducibility - such concepts regarding in particular the philosophy of science as <u>causality</u>, <u>determinism</u>, <u>differentiation</u>, <u>emergence and classification</u>. Where necessary and/or applicable, the emphasis has been put on those aspects of these concepts as they relate to life sciences, <u>with special reference to the concept of evolution</u>.

The three main parts of the dissertation are followed by a Conclusion whereby an attempt is made to formulate a synthesis in which **the semantical open-ended characteristic of the issue** is stressed; it is completed with a somewhat detailed Summary.

KISA ÖZET

Bu çalışmanın konusunu oluşturan **biyolojide ya da canlılık bilimlerinde indirgeme** sorunu, son yıllarda bilim filozoflarının dikkatlerini gittikçe daha çok çekmeye başlamıştır. Ancak "indirgeme" terimi, felsefenin değişik alanlarında çeşitli mantıksal-anlambilgisel işlemler için ve bilgikuramsal amaçlarla kullanılagelmiştir. Bütün bu işlemlerdeki ortak nokta, ister bir tasımın önermeleri ya da doğal sayı kümeleri, isterse moleküllerin yapısı ile molekül düzeyindeki olgular ya da ruhsal süreçler olsun, az ya da çok karmaşık bir yapının, daha temel, daha yalın bir anlambilgisel açıklamasını yapma çabamızdır. Felsefi açıdan daha teknik bir anlatımla bütün bu işlemlerin ortak yanının, Occam'ın bıçağı olarak bilinen kavramsal iktisat ilkesinin kullanılması olduğu söylenebilir. Burada amaç, (simgesel mantık ya da matematikte olduğu gibi) soyut yapımlarla ya da (bilimlerde olduğu gibi) empirik varoluşla ilgili daha temel bir düzeye ulaşmaktır. Böyle bir çaba, felsefe etkinliğinin en başta gelen amaçlarından biri olan, karmaşık soyut yapımları ya da empirik düzeyde olup bitenleri açıklayabilecek en yalın kavramsal yapıyı bulma eğilimi ile tümüyle uyuşmaktadır.

Kuramların indirgenmesi ve bunun değişik yönleri de içinde olmak üzere indirgeme işleminin genel nitelikleri, bu çalışmanın birinci bölümünün konusunu oluşturmaktadır. Onun çekirdeği konumundaki ikinci bölümde **biyolojide indirgeyicilik sorununun** çözümlenmesi, bu arada empirik dünyadaki örgütlenme düzeylerinin oldukça ayrıntılı bir tartışması yapılmaktadır. Bir örnek olarak Kalıtım Alanındaki İndirgemenin, daha geniş olarak biyolojik olanın fiziksel olana indirgenmesi sorunu kapsamında ele alındığı bu bölümde, biyolojide indirgeme ve buradan çıkışla genel olarak indirgeme işlemi, kısmi açıklama olarak belirlenmektedir; buradaki "kısmi" terimi niceliksel olmaktan çok niteliksel bir anlam taşımaktadır. Bunun yanında, yeni ortaya çıkış, uygunluk, nedensellik ilişkisi ve üstüne eklenim gibi kavramlar da, **indirgemenin** felsefi-kavramsal ya da mantıksal-anlambilgisel düzeyde **açıklama olarak görüldüğü** böyle bir bağlamda tartışılmaktadır.

Çalışmanın üçüncü bölümünde, nedensellik, belirleyicilik, farklılaşma, yeni ortaya çıkış ve sınıflandırma gibi özellikle bilim felsefesini ilgilendiren belli kavramların indirgeme ve indirgeyiciliğin ışığında ortaya çıkarılabilecek yönleri tartışılmakta; böylece bu bölüm çalışmanın **olanaklı sonuçlarını** içermektedir. Gerekli ya da uygulanabilir olduğu yerlerde bu kavramların özellikle yaşam bilimlerini ilgilendiren yönleri vurgulanmıştır. Bekleneceği gibi, evrim kavramının burada özel bir yeri bulunmaktadır.

Çalışmanın başlıca üç bölümünü izleyen Sonuç bölümü bir bireşimin yapılmasına yöneliktir; buradaki bireşimde **sorunun anlambilgisel açıdan açık uçluluğu** vurgulanmıştır. Onun son bölümünü ise kapsamlı, az çok ayrıntılı bir Özet oluşturmaktadır.

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Although it would certainly not be the most technical part of any dissertation, the Acknowledgment section may not be the easiest one to write, particularly perhaps in a case like mine in which the student is older than the majority of the members of the examining committee. All the same, and in however an incomplete manner, I would most sincerely like to express my feelings of gratitude to those people whose help has been essential, at different levels and in differing degrees, to the completion of this work.

As in the case of any dissertation, and of any academic-professional work in principle indeed, my thoughts have been greatly improved in the course of my discussions with different colleagues on the topics relevant to the related universe of discourse, both in Turkey and abroad. Some of these people, for the most part philosophers, doctoral students of philosophy and my students from my medical circle, have also been very helpful in that they have urged me to go on with my thesis at times when I had to devote a great deal of my time to academic and professional work, routine or otherwise, and had thus difficulty in allocating even a few hours to my work as a student.

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INTRODUCTION AND PRESENTATION

What the title of the present work may suggest would apparently seem as a topic concerning exclusively the philosophy of biology. But reduction is a subject considered by philosophers in quite different areas of their comprehensive and multi-aspect activity.

The qualifying term "overall critical" mentioned in the subtitle might characteristically imply a general philosophical concept, namely, "epistemological". Another term that would immediately asoociate itself with the latter is, of course, "ontological". And although one might be inclined to doubt whether there could be an ontological reduction at all, as I shall have the opportunity to consider, my purpose in qualifying the term "analysis" as overall critical is due to the need of a stress on the predominantly conceptual aspect of this essay.

Reductionism and antireductionism, as two opposing doctrines or claims, seem to be age-old currents of thought in the evolution of both philosophy and science, assuming different forms in different periods according to the main philosophical trends and the dominant views in scientific thinking. Such seems to have been the case, above all, in what is called the philosophy of mind, in biology and medicine. Accordingly, biological and psychological phenomena have come to be seen, on the one hand and to a not negligible extent, in the light of the physical and/or chemical approaches and theories of the time and, on the other hand, irrespective of the latter. And today, this thesis-antithesis complex appears to be no less a significant topic in different areas of philosophy, sometimes in greatly differing ways.

Whether, to repeat, one could speak of an ontological reduction will be made clear in the passages to come, both through direct consideration and indirectly as a result of our conceptual clarification. By way of a general preliminary remark and with a view of clearing the ground, however, one could point out that the most primitive, coarsest and the most blatantly expressed kind of reductionism would take the ontological form, "... nothing but..." or "... no more than..." - "men are nothing but machines", "theories are nothing but conventional products of the human mind", "love is no more than a habit", and so on. The logico-linguistic and, I think, uncritical form of "A is nothing but, or no more than, B" signifies in its strong sense, the near identity of "A" and "B". Understood in a weaker sense, it would signify a class relationship which would leave little room for the entity "A" to possess other properties ensuring its belonging to at least one other class or set. I think no one would assert, sensibly speaking, that men, theories and love would have no other aspects than the respective ones mentioned.

Considered in a more tolerant manner, all one could say would perhaps be that inevitable class relationships do exist in such cases but that being stated in a partial if not elliptical form they may only be implied, or are expressed in an imputed way. And so far as the class "B" is concerned, to present a fuller account in these cases one must introduce the apparently omitted phrase, "a form of" - "A is nothing but, or no more than, a form of B". This operation may not be the whole answer to the original difficulties, but evidently it completes the missing dimension or dimensions giving us a chance, at least to save the appearances. However, one could still ask the question whether reduction is an ontological necessity (to be formulated in tolerable or "non-reductive" ways), or a conceptual procedure, or whether it is both. But the whole issue will not have been clarified, apparently, until after it has been fully analyzed.

In the first part of this work concerned with a conceptual analysis of reduction and reducibility, I shall begin with treating it from an etymological-semantical and then from a philosophical standpoint. Later, I shall briefly discuss "kinds" of reduction in philosophy with a view to clearing the ground further and delimiting the scope of our universe of discourse to the consideration of theory reduction to make way to a philosophical-biological presentation of the problem in hand by having eliminated others considered in different domains of philosophy. In doing so, we shall also have seen our problem in a different perspective by means of comparisons between different uses of the term "reduction".

In the last section of Part 1, I shall consider the concepts of matter and the physical as another prerequisite, so far as I can see it, to our main argument to be presented in the second Part, "The problem of reducibility in life sciences". I shall begin this part with an exposition of the main views on our problem. Evidently, Part 2 is the central or core part of the work. I shall first consider here the concept of the levels of organization in nature, and then discuss whether or not there exists a conceptually significant difference between the inorganic and biological realms, understandably in the light of the concept of levels. Reduction in genetics as a case in point and as related to reducibility in life sciences will constitute the subject matter of the third chapter. This will be followed, in the fourth and last chapter of this Part, by an account of reduction (in biology and elsewhere) whereby it is regarded, from a philosophical point of view, as a form of partial explanation of life (and other sorts of) phenomena.

Part 3 will be devoted to a discussion on the implications of the foregoing points, whereby I intend to consider first the principles of causality and determinism in connection with reducibility, to be followed by a treatment of reducibility, in turn, in the light of the concept of evolution. Among further implications to be discussed in this context will be the topics of differentiation (diversification), extension and emergence, all being evidently significant topics in biology (although they can be considered in other basic sciences as well). Possible ontological implications will be dealt with together with problems of classification which might ensue.

The work will be completed by a "Conclusion", a final (and, at the same time, non-final) synthesis whereby I am hoping to be able to present an overall picture of our main discussion, with an emphasis on the philosophical and theoretical scientific significance of the whole matter.

PART ONE

THE CONCEPTS OF REDUCTION AND REDUCIBILITY

Introductory Remarks

This part of the study is planned to be conducive to a conceptual clarification in the matter of reduction in general, and thus to serve as a preparation for a discussion on reducibility in biology.

Clearing the ground is necessary for, evidently, biological reduction should be regarded as what might be called a specific case of reduction in general or, to put it more precisely, as the latter's differentiated extension into the field of biology. What I mean by the term "differentiated extension" will be made clear later in the work after we have discussed the concepts of differentiation and extension in ontological terms, and this although I have used the term here, understandably, in an epistemological sense.

Following the customary if not necessarily established course in the semantical treatment of scientific and philosophical terms, and of any term in principle indeed, I intend to begin the chapter with an etymological analysis of "reduction" and "reducibility", departing from an introductory treatment of the more basic verb form to reduce. The latter, being the adaptation of the Latin re plus ducere, means in its core sense "to bring or lead back". In its sense relevant to our context, it would mean "to bring down"; "to diminish to a smaller number, amount, extent, in size or value, and so on, or to a single thing"; and, also, "to lower, diminish, lessen"; "to bring under rules or within certain limits of description". Put briefly, it would denote an economy in terms of the constituents of what we might call a whole, say a system or collection. More clearly perhaps, the aim in the background seems to be the conceptual preservation of some parts or components of the whole in question at the expense of other parts or components that could be eliminated or kept apart for a certain purpose, above all to economize concepts and formulations in our attempt to explain the functioning of that whole.

The adjectival derivative reducible clearly signifies "capable of being reduced". In one of the above senses, for instance, it would mean "capable of being diminished to a smaller number, amount, extent, in size or value, and so on, or to a single thing". Further we could understand by the term "capable of being brought under rules or within certain limits of description".

Reduction is obviously the related act. In two of the above instances, for example, it would be "the act of diminishing to a smaller number, amount, extent, and so on, or to a single thing," or that of "bringing under rules or within certain limits of description."

As the expressions mentioned must show, I think, the term "reduction" as well as its more basic verb form "to reduce" has essentially epistemological connotations. It appears to signify our mental (conceptual) and/or linguistic (definitional) attitude towards what exists or is described. This point is important in our discussion in that it must always be kept in mind in our attempt to clarify the related concepts in different areas of philosophical endeavour, as we shall have the opportunity to see in chapter 1.3.

Lastly, reducibility would mean "the state or capability of being reducible," a capability whereby something can be diminished to a smaller number, amount, extent, and so on, or to a lower level, thus "occupying a lesser position, or having less."

Chapter 1.1

THE CONCEPT OF REDUCIBILITY FROM A PHILOSOPHICAL POINT OF VIEW

In our attempt to clear the ground in a discussion on the concept of reducibility, we could next undertake the task of analysing the issue in a broader philosophical perspective. As would generally be known, it was Occam who first pointed out the significance of "not multiplying the entities beyond necessity" in the logical treatment of categories. This general principle of logical (or epistemological) economy, which later came to be known as Occam's razor, has been variously formulated, another one being, "it is vain to do with more what can be done with less." We should not, according to the principle and so far as could be done, have a recourse to unnecessary epistemological entities to give an account of any "ontology", or a unit or collection of units of study whenever we can do away with them. In other words, whatever there is must be accounted for in terms of as little constituents as possible, be it parts of a system, determinants of a phenomenon, or antecedent conditions of general states of affairs, and without the addition of any admittedly superfluous or redundant entity (or property, relation, process).

There appears to be quite important semantic implications of Occam's razor or principle of economy, because the delimitation of the scope of terms, hence their definitions, necessitate the application of the same or at least a basicly similar procedure. In more general terms, the conceptual treatment of any philosophical issue, particularly perhaps in the course of clearing the ground and trying to "philosophically found" a basic problem, say concept formation, would require a recourse to the principle.

Evidently, Occam's razor would be considered from the opposite direction too, that is to say, cautiously with a view to making a trimming, but not cutting during this operation too large an amount and thus reducing the set of entities (and/or properties, relations, processes) unduely (as we shall have the opportunity to see, I think, in this work).

The use of Occam's technique of simplifying the universe of discourse certainly demands an ingenuity, not less perhaps in the present context than in the case of many other philosophical issues, for many thinkers of the problem seem to have an inclination to take the similarities between the biological and inorganic realms too far (and evidently as opposed to what we might call the mystifying tendency in which entities are multiplied to explain the inanimate nature by borrowing redundant ones from the living or biological world).

If the above discussion is basicly justified, it must then be clear that although reduction and reducibility are above all conceptual if not strictly epistemological topics, the ontological aspect would always make itself felt, and sometimes strongly I think, in the course of conceptual considerations. Indeed, reduction is ultimately about whether the overall categories, or rather constituents, of the world, that is entities, properties, relations and processes, could be empirically as well as (empirico-) logically expressed, generally speaking, in terms of lesser constituents or units.

The concept of reduction has been applied, somewhat unsparingly perhaps, outside the scope of life sciences and what we might call their differentiated extensions like, for instance, psychology or ethology (or maybe even sociology), to certain problems in other domains such as formal disciplines as well as in those empirical fields with the phenomena of the nonliving world as their subject matter. The issue has also been a very important one in the philosophy of science in general, where the relationship between the "theoretical" and the "observable" entities and properties has always constituted one of the leading or central problems. The matter will be made clear in the next chapter where, I hope, I shall be able to put it forward in its main outline or essential dimensions.

Chapter 1.2

"KINDS" OF REDUCTION IN DIFFERENT DOMAINS

In a discussion on different kinds of reduction in different domains as topics of philosophical discourse, I think two distinctions must evidently be made. First of all, reductions and reducibility problems in empirical fields must be considered in distinction from those of the formal disciplines simply because of the synthetic nature of the former's assertions (and the nonemptiness of their sets) and the analyticity of the latter's propositions (together with their sets' emptiness). There seems to be no connection, except a similarity in bare outline or a pseudo formal likeness perhaps, of any significant conceptual similarity between, say, the reduction of chemistry to physics or that of the biological to the physical on the one hand, and, on the other hand, the reducibility of syllogistic theory to monadic predicate logic or the Kuratowski reduction of the natural numbers to sets ultimately containing the null set. Secondly, we must distinguish between intralevel and interlevel (and intra- and inter-disciplinary) reductions - the reducibility of heat to motion in physics or Russell's axiom of reducibility in logic are instances of the first category while the reduction of psychic or psychological phenomena to brain biochemistry and the Kuratowski reduction just mentioned are of the second type.

Here I intend to give an expectedly concise account of the main sorts of reduction in several forms of inquiry, discussing some of them in some detail while just mentionning others, understandably according to their degree of interest to us. We may begin with examples of logic, the essential formal discipline, which can be put into the very bottom of a "hierarchy" of disciplines, certainly at most in an ad hoc manner and not forgetting at all the above distinction between the empty and empirical sets (Comte's logical and epistemological orders of "sciences" could deserve a passing remark in this context).

<u>Reduction in traditional logic</u> is the method of rearranging the terms in one or both premises of a syllogism or argument form to express it in a different figure. Taking as primary the first figure, Aristotle for example "reduced" the second, third and fourth figures to the first:

No A is B
All C is B

No C is A can be reduced to a first figure syllogism by simply converting the first premise to its equivalent, "No B is A".

In <u>the reduction of syllogistic theory to (monadic) logic</u>, the natural language statements with which the former theory deals are correlated with formulae of the special artificial language of the latter. If the necessary constraints on the latter's terms are also imposed on their counterparts in the predicate calculus, it turns out that any deduction which is justified in syllogistic theory is a theorem of the predicate calculus. Thus, syllogistic theory is "reduced" to predicate logic in a way which satisfies both conditions of reducibility, namely, if (a) every term of the theory T2 is representable in terms of some combinations of terms of theory T1, and (b) every theorem of T2 is also a theorem of T1. (This, by the way, is apparently a clear example of the reduction of one theory to another.)

As for the <u>Kuratowski reduction</u> of the natural numbers to sets ultimately containing the null set, here the natural numbers are represented as sets by a method due to K. Kuratowski. The method in question is a very simple mapping from the naturals to some sets, the natural number "0", zero, being mapped into "ø", the null set. And each natural number <u>n</u> is mapped onto the set which has the null set as its n-deep number. The Kuratowski image of the natural number n is K^(n) (ø), the result of applying the K-operator n times successively to the null set. Thus conceived, many simple operations among natural numbers are reflected in the set-theoretic reconstruction as operations on the power indices of the K-operator.

This mapping would induce a set-theoretic model of simple arithmetic, a model whose domain consists of sets. A set of axioms could be specified for the model in question which would yield analogues of most theorems of simple arithmetic. It could then be argued that the resulting theory was a genuine reduction of simple arithmetic to set theory. But such a reduction would have no "epistemic" or "ontological" significance, because the reducing theory has been constructed on the image of the reduced theory - the only reason we are interested in the reducing set-theoretic theory is that it reflects simple arithmetic. It would therefore be quite unjustified to suggest that natural numbers no longer need to be considered as separate entities, or that arithmetic need no longer be studied. While every natural number may be represented as a K-set, this in itself is no reason to assume that what they represent, the natural numbers, may thus be disregarded, banned from discourse and excluded from our studies. It is the properties of the natural numbers per se, and not of those K-sets, which are of interest to mathematicians (Rızatepe, 1984).

As this observation must show, that every term of T2 is representable in terms of some combination of terms of T1 does not of itself imply that the things about which T2 speaks need no longer be assumed to exist. The former may be a necessary condition for the latter to hold, but it is certainly not a sufficient condition (Rızatepe, 1984).

This critical discussion on the Kuratowski reduction is added here with a view to giving a general idea of how a reductionary treatment in philosophy is as a rule realized, both in the operational and conceptual senses of the term, not disregarding the fact that the example given here is between two formal disciplines with empty sets constituting their subject matter.

So far as the empirical domains are concerned, what is significant for us in this essay is certainly the reduction of the biological to the physical or, in unequivocally epistemological terms, that of biology to physics. Before discussing our main theme more closely, however, it would be appropriate to mention and treat here quite briefly certain other forms of reduction in or between sciences.

The reducibility of heat to motion in physics is formulated, as is known, in the kinetic theory of gases, in which the phenomenon of heat is expressed in terms, or taken to be the result, of the motions of gas molecules. In this context one could also speak, perhaps, of a transformation of one phenomenon into another (hence between two concepts) in physics.

It might perhaps be interesting to remember now that many gases, being constituted by compound molecules possessing more than one sort of atom, are in fact chemical structures. What should be said about this obvious and apparently justifiable claim would be that such gases are physical structures as well as chemical compounds, and that they would either constitute a topic of physics or chemistry, understandably depending on the level of the argument. Here, the physical aspect comes to the fore, and it does not matter at all whether a gas is a simple or compound one so far as the kinetic theory is concerned.

In the reduction of chemistry to physics, molecular phenomena are considered in terms of what happens at the atomic level, making an allegedly "classical" if not outmoded and, in my view, still useful distinction, trying to put the matter in a clear perspective.

Defined concisely, chemistry is the science of the formation, structure, properties and interactions of molecules. The reductionist question in this context would be, "Can all, or almost all, the behaviour of molecules be seen as the direct extension of the properties of their lower-level constituents, manely, atoms (and further still, subatomic particles)?" We may also ask the question in the reverse direction, considering the issue as one of emergent qualities in the hierarchical organization of matter: "Do chemical compounds show new qualities not possessed by their constituent parts, whether atoms and/or simpler molecules?" In the case of water as a frequently considered example, for instance, does the H2O molecule possess different or only similar qualities as compared with H2 or O2, jointly or separately? The answer seems to lie in the recognition that besides purely physical qualities such as weight, freezing and boiling points and so on, and more significantly I think, water assumes a different physical phase and becomes a fluid under those conditions in which oxygen and hydrogen are "normally" gases. Due to its new, emergent (evolutionary) characteristics, as well as its ubiquitous presence, water enters a multidimensional relationship with other chemical (and physical?) units in nature, occupying, in different phases and forms, great areas and spaces. It becomes, with a unique circulation between these phases and forms, the very source of an utterly different and immensely complex level of emergence - that of the biosphere. It becomes, at the same time, the basic component of the structure of living beings and constitutes the infrastructure of their internal milieus, as well as a very significant part, qualitatively and quantitatively, of their external environment. Many essential geological, geographical and evolutionary happenings and ongoing phenomena have been the product of water's primary (and secondary, tertiary...) qualities such as good solvency and the capacity to unite chemically or physicochemically with carbon and nitrogen to form biochemical building blocks of the biosphere; evidently quite relevantly in our context, those qualities that are not shared by its constituents at a lower level, hydrogen and oxygen. (I think the question of "intrinsic" as opposed to "relational" properties need not necessarily concern us here.)

An expectedly classical or traditional claim would be that to be able to speak of "new" qualities "emerging" from the unification of hydrogen and oxygen as constituents of water, there must be a third (and fourth, and fifth, and so on?) factor entering the reaction so that properties not observable in the constituents before the synthesis could appear. This would be the typical a priori approach of speculative philosophy to the understanding and explanation of the empirical world, with an evidently redundant and actually imaginary entity (or entites?) defying an empirically rational account for its (their?) existence. There do exist factors indeed that enter and enhance chemical reactions. However, these are chemical substances called catalyzers (enzymes in the case of living entities), and not any speculatively philosophical "thingish" something, expressed in a typically speculative philosophical language, with no rationally comprehensible and calculable empirical, ontic status; and leaving the scene, so to say, at the end, the catalyzers exert no qualitative effect upon the result(s) of the reaction. The application of Occam's razor is understandably needed here to do away with such superfluous or redundant imaginary "entities".

I am not in a position to tackle with the problem of whether the success or failure of a reductionist thesis in one of the formal disciplines would imply a similar outcome for a reduction in a subdomain of that discipline. Nor could I dare to analyze the issue when it is a matter of taking one successful (or unsuccessful) reduction, say in mathematics, as a support for a similar result in some subdomain of logic, and vice versa.

In the case of the empirical fields, on the other hand, and as must generally be known, an intertheoretic reduction between two different or separate disciplines, say between chemistry and physics, and also between biochemistry and chemistry, is as a rule ragarded as a strong support for the possibility of a reduction at higher levels, between biology and biochemistry for instance. And this the very topic of this study.

Further, however, we might entitle ourselves with making comparisons in the matter of reducibility between the formal disciplines on the one hand and those in the empirical sciences on the other. Could we assert that a successful reductionist solution of a general nathematical problem would serve as a "basis of action" for a similar attempt in the case of, say, the psychological theories being reduced to their biological or neurological counterparts? Or should we regard, conversely, an intertheoretic reduction between biology and physics as a support for a reducibility thesis between, for instance, two subdomains of logic?

To stress the point again, there appears to be no analogies with supportive evidence between the reduction in formal disciplines with their analytic propositions giving us no information about the world, and the empirical sciences with their synthetic assertions describing and/or explaining the world to us. As mentioned earlier, there could at best exist, and there may indeed be, representational analogies between reductions in the two domains with no philosophical support and just serving perhaps as a bare outline for illumination by way of a comparison of the similarities. The definite demarcation line separating the two domains, or rather superdomains, so far as both their methodological and epistemological statuses are concerned, would not allow us, I think, to make valid explanatory transitions. There appears to be no "organic" or real connection that would render such transition possible and/or justifiable.

Furthermore, reduction in and between the two formal disciplines seem to have a predominantly operational character. This aspect is apparently of secondary importance in the case of empirical fields; here the matter of reducibility appears to be rather a "doctrine" or, to use a simpler and perhaps more justifiable term, a "thesis" with an either partial or almost totally exhaustive explanatory claim.

REDUCTION(S) IN PHILOSOPHY

A Schematic Outline

The Level of Distinction: The Formal and the Empirical

Formal Disciplines

(A) In Logic

(1) Reduction in Traditional Logic

(2) The Reduction of Syllogistic Theory to (Monadic) Logic

(3) Russell's Axiom of Reducibility

(4) Carnap's (what we might call) "Logico-Linguistic" Reduction

(B) In Mathematics

- The Kuratowski Reduction of the Natural Numbers to Sets Ultimately Containing the Null Set

Empirical Domains

A Basic Philosophical Level of Distinction

Ontological Reduction *

Phenomenological (Transcendental) Reduction

Epistemological Reduction *	} Reduction in general in the
Logical Reduction (TG) *	} Philosophy of Science, and
The Received View - Nagel's Original Account in Theory Reduction	} Theory Reduction in Science(s), } both having the logical } empiricist approach as their departure point

(* So far as I am aware of, the coinage of the latter term and the formation of this triple set is due to Teo Grünberg.)

- Reduction in general in the Philosophy of Science:

  that of Theoretical to Observable Entities - going back to Mach in its extreme empiricist form.

THEORY REDUCTION

In and Between Sciences

General Considerations - Main Views

(1) The "Classical Account" or the "Received View";

(2) The Part-Whole Relationship and Epistemological Reduction;

(3) Indirect as opposed to Direct Reduction;

(4) Intra- and Interlevel (or Micro-) Reductions - Inhomogeneous or Heterogeneous Reduction - Successional and Explanatory Reductions;

(5) Interfield Theories and Reduction;

(6) Type-Type and Token-Token Reductions;

(7) Compositional and Evolutionary Theories in connection with Reduction (and Deduction).

Certain Specific Cases

(1) Reduction of Heat to Motion :

Not intertheoretical in the sense of the reduction of one theory to another; deduction seemingly unlikely to apply;
intralevel in character (i.e. within physics); represents an interphenomenal reduction in the sense that it relates a certain kind of phenomenon to another - one serving as a causal explanation of the other; could we call it,
also, a nomological reduction because it can be formulated as a natural or scientific law?

(2) Reduction of Chemistry to Physics :

Intertheoretical and/or interfield (interdisciplinary);
deductive preservation seemingly successful; interlevel;
also, nomological in the sense that the laws of the former
can be deduced from those of the latter; a direct reduction

(3) The Reduction of the Biological to the Physical (Sciences) - the Core or Main Theme of the Dissertation.

(4) The Psychophysical (rather to be called Psychoneurological or Psychoneurobiological) Reduction - The Mind-Brain Relationship (but certainly not the traditional mind-body problem!).

A Possible Chart as Related to Reduction:

In the light of the basic level of distinction

		In the Formal Realm	In Empirical Domains
From the Viewpoint of Levels and/or Fields, Discipll.	Intra-level	Reductions in Logic	In Physics: Heat to Motion
	Inter-level	The Kuratowski Reduction bet. Math. - Logic	Chem. to Phys. The Biological to the Physical

Chapter 1.3

THEORY REDUCTION: THE "RECEIVED VIEW" AND THEREAFTER

Section 1.3.1

The "Classical" Account of Theory Reduction

In our time and leaving aside comprehensively historical considerations, our problem is apparently best represented, in epistemological and/or conceptual terms, by the well-known formulation of E. Nagel on what he has called the theory reduction. On his view, and as is frequently mentioned, two conditions must be satisfied so that all the laws of a higher-level ontological theory (T1) could be explicable in the theory of a lower level (T2). First, all the concepts (or terms) Ch of Th should be systematically connected with some of the terms of Cl of Tl, either by synthetic identity statements, explicit definitions or some other semantic relation; this is called the condition of connectibility. Secondly, each law Lh must be deducible from T1, together with the statements that connect the Chs with Cls, and a description of relevant boundary conditions in the vocabulary of Tl; this is known as the condition of derivability (Beckner, 1974).

The above account among the overall models of theory reduction has come to be specifically known as direct reduction, and has also been contributed to by H. Woodger and W. V. Quine. Expressed in slightly different terms, and assuming that the reducing, that is lower-level, theory is an adequate one, the basic terms of one theory are related to the basic terms of the other, and the axioms and laws of the reduced, higher-level theory become derivable from the former (Schaffner, 1967).

Section 1.3.2

Reduction as a Kind of Deduction

Reduction has been viewed in different ways - for instance, as a well defined, structurally universal operation, that is to say, as a kind of deduction, holding between well understood and clearly defined and formalized theories. Further, it has been analysed in terms of well understood functions in scientific and metascientific inquiries such as: (a) unification; (b) systematization; (c) the consequent increase in precision and clarity; (d) ontological and (e) postulational economies; (f) explanation of the reduced theory and/or phenomena; and possibly (g) correction of the now supplanted or reduced theory. With some exceptions, however, most writers in the seventies have advanced increasing criticisms, even of the basic presuppositions and motivations of this view of reduction (Wimsatt, 1979).

Section 1.3.3

Successional and Interlevel Reductions

One of the important distinctions in the matter of reduction is between what Wimsatt has called successional and interlevel or explanatory reductions, based on a combination of logical and functional grounds. Most of the logical dissimilarities between these two sorts of reduction appear to be the products of the fact that while the former involves a kind of similarity relation, similarities here being only local and conceptual in structure, the latter is an identity relation in the form of compositional identity. And while identity relations are transitive, similarity relations are not. Accordingly, one should not be surprised to find that successional reductions are intransitive, enough of them being added, in succession, up to a replacement of one theory by another. By contrast, interlevel reductions are assumed to be transitive, and this no matter how many levels are involved (Wimsatt, 1979).

Section 1.3.4

An Intermediate Position In Reduction

According to an "intermediate" reductionist position, although the reduction of biology to physics, for instance, cannot be effected at present, it is possible in principle. Thus, the factual reduction is made contingent upon further progress in the biological or in the physical sciences, or in both (Ayala, 1968). This view will be mentioned later on in connection with Hull's critical evaluation of reduction in genetics (section 2.3.1). In the light of its antireductionist counterpart in biology in general, indeed, such a reduction is not possible in principle because organisms are not merely assemblages of atoms and molecules, nor even of organs or tissues standing in merely external relation to one another. They are alleged to be 'wholes' that must be studied as wholes and not as the 'sum' of isolable parts (Ayala, 1968).

Section 1.3.5

The Rationale in Reductionism - Its Critique

The rationale for reductionism ultimately rests on the reductionist's concept of causality, whereby he holds that the cause of any event is the occurence of a preceding physical event. By physical event he means, of course, that an ("organic") event is describable in terms of the actions of inanimate entities. Consciousness, for instance, is the end product of a complex sequence of physico-chemical events, each of which being fully determined by preceding physicochemical events, and it thus becomes an epiphenomenon at the end this causal chain. As a mental phenomenon it can have no causal efficacy, that is, although it is caused, it cannot be the cause of any further events. Accordingly, and being literally conceived of as a metaphysical dead end, the reductionists find no reason to use the fact of consciousness as an explanatory concept, because if a phenomenon can cause nothing it can explain nothing. And a phenomenon which can cause nothing, having thus no effects, cannot be measured (Efron, 1977).

As Efron points out, however, there are two implications of all psychoneural identity theories which contradict the principle of reduction. A blatant contradiction is the argument that mental states are identical with physicochemical states while maintaining at the same time that the two can be correlated. Because to correlate is to compare the occurence of, or the association between, two different existents, with the causal relationship being unknown or unstated. The moment one attempts to establish a correlation one has implicitly ackowledged that the two phenomena are different, as in the case of a particular frequency of discharge of neurons in the optic nerve and a particular experience of "brightness" for instance. Secondly, to maintain a psychoneural identity theory one must implicitly concede one's inability to describe the causal relationship between the physicochemical events in the brain and conscious experiences. While to correlate physico-chemical events in the brain and conscious experiences is a scientifically appropriate activity, it cannot be construed to be epistemologically identical with an explanation, which is a statement of the causal relationship between the events which have been correlated. And to accept this epistemological position would necessarily lead to the view that consciousness cannot be explained by the laws of physics, this being the denial of the validity of the principle of reduction (Efron, 1977).

Section 1.3.6

Nagel's Account as a Logical Empiricist View

In the logical empiricist view, theories are axiomatic systems and reduction is the deduction of one theory from another. According to Nagel, for example, questions about reducibility can be profitably discussed only if they are made definite by specifying the established content at a given date of the sciences under consideration. Thus, the contrast between reduction and replacement ceases to be a dichotomy and becomes a continuum (Hull, 1979b).

Section 1.3.7

Different Aspects of Theory Reduction

As we are concerned in this chapter basicly with theory reduction, we need to stress certain aspects of theories as conceptual structures with the function of explaining a wide range of apparently interrelated phenomena. The task of the philosopher of science has been further analytic-conceptual treatment of theories from different points of view such as consistency, semantics, correspondence, relation to other theories (as in the case of reduction, for instance) , and other philosophical concerns. As Hull (and also others) points out, however, theories as they are set out by scientists are usually too incomplete and ill-formed for the philosopher's purposes. The latter must extract them from the literature, develop them, and formulate them explicitly, and he is placed, frequently perhaps, in a dilemma: he must extract the scientific examples which he is studying from the literature of science and reconstruct them, but he cannot do this so extensively that they can no longer function as evidence for his views on the nature of science (Hull, 1981).

Section 1.3.8

Indirect as opposed to Direct Reduction

At this stage of our review of theory reduction, we may mention direct and indirect reductions, a distinction made by Causey (and also by others; cf. section 1.3.1). The possibility of a structure at one level cannot be deduced from the laws at that same level, but it can be deduced from the laws and boundary conditions at a lower level. The possibility of DNA molecules can be deduced, in principle, from quantum mechanics and its boundary conditions with a necessary emphasis to be put on the 'in principle' clause. While such derivations have been performed for relatively simple molecules, they become increasingly unmanageable as the complexity of the molecules increase; and the steps from molecules to cells and organisms are accompanied by a geometric increase in the difficulty of such derivations, which have been called by Causey direct reductions. In indirect reduction, the actual existence of a whole is explained with the help of theories at levels higher than that whole. As pointed out by Causey, such an explanation might be reduced to a level lower than that of the object (Hull, 1981).

Section 1.3.9

Intra- and Interlevel Reductions

In a parallel but more comprehensive manner, we could distiguish between intra- and interlevel reductions. As is clear from the prefixes used, the first one concerns theories and laws at the same level, as in the case of Kepler's law dealing with the planets and the sun, and Newton's law on the motion of all bodies, including the planets and the sun, with close approximation; in such a situation, the reduced formulation becomes a special case within the framework of a more comprehensive formulation. In the second one, called also microreduction (see Grene, 1974b and also section 1.3.3), the two theories deal with phenomena existing at different levels of analysis; as Causey, again, remarked, such an interlevel reduction is, roughly speaking, "an example of the behavior of a structured whole in terms of the laws governing the parts of the whole" (Hull, 1981).

According to the logical empiricist's analysis, a scientific theory is a set of inferentially related statements, a few of them being taken as axioms and others being derived (from the latter) as theorems. In theory reduction, in the light of this view, the axioms of the theory being reduced are derived from those of the reducing theory with the aid of appropriate reduction functions that associate certain key terms and phrases in one theory with corresponding words in the other. But the two theories must first be reconstructed so that the necessary derivations can be shown (Hull, 1973).

So far as the formalism of theory reduction is concerned, the reduced theory may change to T*2 as a result of revisions in it necessitated by a desire to make it to conform to evidence as highlighted by the reducing theory T1. It may happen, also, that T1 itself must be altered for a reduction of T2 or T*2 (as Maxwell's electromagnetic theory, for instance, was altered and supplemented by the electron theory of Lorentz to explain more adequately dispersion phenomena and the results of experiments done in the field of optics of moving bodies) (Schaffner, 1976).

Obviously, I think, what particularly concerns us here is interlevel reduction, although we can never keep aside certain general or basic issues of reductive operation such as connectibility and derivability. It seems to me that the matter will be clearer after a somewhat detailed treatment of the levels of organization and when we have considered the relationship between the organizational levels in biological systems or entities in Part 2.

We may now point out that while, in the view of Wimsatt, intralevel reduction refers to a relation between theories and although changes in the meaning of key terms do require elaboration on the part of the new (reducing) theory, interlevel reduction refers to the development of a theory which comes to link different levels (in epistemological terms). In the case of the relationship between the Mendelian and molecular theories of genetics, for instance, the term "gene" shows a change in meaning in the molecular theory (as we shall dicuss later on) and the phenotypic and the genotypic levels are linked via enzymatic pathways, apparently, though, not exhaustively (Zucker, 1981).

One of the concepts of theory reduction, and in our case "the eventual reduction of biological to physical science", would be an "inhomogeneous" or "heterogenous reduction", a term coined by Nagel. A reduction is called inhomogeneous by him when the two theories involved do not have a common conceptual apparatus, that is to say, when the reduced theory contains concepts not found in the reducing theory from the beginning; this would also imply, certainly, an asymmetry (Roll-Hansen, 1969). In other words, in this kind of reduction some but not all of the concepts of the secondary theory are shown to be eliminable, and being from a higher to a lower level heterogeneous reductions are transitive in that if one theory reduces to a second and the latter to a third then the first reduces to the third. In heterogeneous reductions, further, it has been claimed that the entities of the secondary theory are collections of entities of the primary theory. In what is called "homogeneous reductions", on the other hand, the two theories (are said to) deal with the same entities, and none of the concepts of the secondary theory may be eliminated; being intralevel, homogeneous reductions are not generally transitive. In addition, in contrast to heterogeneous reductions, there are many examples of successful homogeneous reductions (Friedman, 1982). (See also section 1.3.3.)

Section 1.3.10

Interfield Theories and Reduction

As certain writers have questioned, however, the current emphasis on the relations between different scientific theories has obscured the interactions between different areas or fields of science (as a very much related topic). The relation that Ernest Nagel has discussed as the reduction of one branch of science to another, for instance, is in reality nothing more than the derivational reduction of the theory or experimental law of one branch of science to that of another. Certain writers are interested in the interrelations between the areas of science that they call fields. Cytology, genetics, and biochemistry, for instance, are more naturally (and conveniently) called fields than theories. Fields may have theories within them, for example the classical theory of gene in genetics; these writers would call such theories intrafield theories. More importantly for them in their context (and in mine here), interrelations between fields may be established via interfield theories. For example, the fields of genetics and cytology are related via the chromosome theory of Mendelian heredity (Darden and Maull, 1977).

Seen in a developmental perspective, one should clearly distinguish between fields and intrafield theories, for "a field at one point in time may not contain a theory, or may consist of several competing theories, or may have one rather successful theory. Well-confirmed laws and theories may become part of the domain and a more encompassing theory be sought to explain them... fields do not compete, nor do theories in different fields..." And "one field does not reduce another field; reduction in the sense of derivation would be impossible between such elements of a field as techniques and explanatory goals" (Darden and Maull, 1977).

It must be clear, I think, that as Darden and Maull point out, and in spite of the fact that they do not bear the relations formerly thought to exist between theories, fields may be related to one another. These relations between fields would produce a different type of theory, the interfield theory (Darden and Maull, 1977). While several examples might be given from the development of life sciences, the most salient one seems to be the chromosome theory of Mendelian heredity bridging the fields of cytology and genetics, and this is the one I intend to consider in this study as an instance for reduction in biology.

Section 1.3.11

Historical Unification as Opposed to the Logical Unity of Science

Processes of linkage between biological and physical sciences have contributed to a gradual "unification" in scientific activity, which is a historical fact ignored (in general) by the philosophers with their methodological commitment to the "logical unity of science". And anticipating a logical unity among sciences, they commonly interpreted reduction as the deductive-nomological explanation of one theory by another. Of course, deductive relationships have the notable advantage of being truth-preserving (Maull, 1977). At what cost, however, is an issue which we shall critically consider later on in the course of our main discussion. Besides, historical development of sciences and their logical relationship if not unity does not seem to be necessarily exclusive but rather, I think, complementary, although we might hardly find an occasion here to elaborate the issue directly. I do hope that the consideration of the issue of reduction in genetics would give important clues as to the "togetherness", so to say, of the logical and historical aspects of scientific development in biology.

Section 1.3.12

Analysis and Reduction

One of the possible conceptual mistakes in connection with our discussion is the confusion of reduction of one theory to another with what is called analysis, that is the strategy of breaking a whole into its parts in order to understand the properties of the whole. What philosophers of science customarily have in mind when they speak of reductionism is not that operation per se but the two necessary conditions of connectibility and derivability. Analysis as a procedure plays a role in Nagel's sense, too, as in the case of attempting to reduce thermodynamics to mechanics in which gases as thermodynamic systems are analysed into their component parts, atoms and molecules, and then to apply the laws of mechanics in order to derive the laws of thermodynamics. But the view that we can best understand a whole by analysing it into its component parts might be better designated as the analytic approach (rather than reduction) (Howard, 1979).

Section 1.3.13

Deductive Preservation and Radical Unrepresentability

If deductive preservation is on the one extreme of a scale in the relationship between theories, at the other end is the radical unrepresentability of one theory in the other theories because the entities and properties of the former has no, not even an inexact, analog in the latter - material theories of heat, for instance, were radically unrepresentable in later theories based on molecular motion. As a slightly less extreme case, one might mention Dalton's first theory of gases which explained the constant proportion of air and the law of partial pressures by postulating a repulsive force acting distinctly between molecules of the same compound. The kinetic theory of gases explained the same phenomena on the basis of Brownian motion of all gas molecules. While the two theories share molecules (as their ontological units), the latter's underlying forces are radically different in the two theories, and thus neither theory preserves the other (Goosens, 1978).

In reality, there is a host of possibilities between radical unrepresentability and deductive preservation. Parts of a theory, for instance, could be preserved, or there may be, in the commitments of the other theories, objects and properties close to what a theory requires. One might be able to show that a theory is approximately preserved, that is to say, what one theory claims would be approximately true on some other thories. In some other cases, a theory may be restrictedly preserved, that is, what the theory says is exactly or approximately true for some restricted situations. Kepler's first law, for instance, is restrictedly preserved in Newtonian mechanics in two body systems, and approximately preserved in some multiple body systems (Goosens, 1978).

In the case of comparable theories, the high end of the scale of preservation has been traditionally called reduction, and the low end replacement. So long as we understand that the reality is the degree of preservation, whether reduction includes only deductive preservation or a segment of the end of the scale becomes a fruitless linguistic question. To the degree that the theories in genetics are preserved by molecular genetics, for instance, we could defend the relation as reduction (Goosens, 1978) (italics mine).

Section 1.3.14

A Functional View of Reduction

Opposite to this deductive, formalistic, logical, or in short structuralist (and "received") account of theory reduction, as discussed by Goosens, is the functional view whereby, according to Wimsatt, the related concepts of reduction, replacement, identity and explanation can yield important clarifications of their nature. The functional viewpoint is perhaps best explicated, in the latter author's view, by expanding upon and modifying Schaffner's model, with its many useful features and although the end result becomes quite different. Schaffner distinguishes between and includes both a derivability condition between the reducing theory (T1) and a corrected version of the reduced theory (T2*), and a condition of strong analogy between T2* and its uncorrected predecessor, T2. And while these two relations are prototypic of two distinct relationships, each of them has been called 'reduction' (Wimsatt, 1976).

Schaffner's condition of strong analogy is closely related, adds Wimsatt, to what he has called 'successional' or 'intra-level' reduction. It has the features of being (1) a relation between theories, unlike explanatory reduction which is not (except in very simple cases); (2) the opposite of replacement (which is closer to and is treated by many as a synonym for reduction - or rather replaceability for reducibility); and (3) intransitive, with a number of them 'adding up' to a replacement (whereas explanatory reductions are transitive). While the opposition between reduction and replacement is appropriate for successional reduction, it is not for explanatory or interlevel reduction (Wimsatt, 1976). (See also section 1.3.3.)

These views will be mentioned again when the relevant points are discussed in later passages.

Section 1.3.15

Type-Type and Token-Token Reductions

Before considering the antireductionist thesis in general and its offshoots in the field of biology, a last point seems to be worth mentioning with regard to the topic of reduction. This is the issue of *type-type* and *token-token* reductions which, as we shall see, are particularly relevant to, and frequently mentioned in the case of, genetics, our central example for our discussion on reduction in biology.

The first one that can be mentioned in this context is called *strong type-type reduction*. Here there exists a simple, one-one equivalence of concepts in the two sciences, such that the laws of the reduced science, S2, can be derived from the laws of the reducing science, S1, as can be shown as follows:

$$
\begin{array}{l}
Ax \dashrightarrow By \\
Zx \dashrightarrow Ax \\
By \dashrightarrow Wy \\
\hline
Zx \dashrightarrow Wy
\end{array}
$$

In the *weak type-type reduction*, on the other hand, a many-one correspondence between the types of S1 and S2 is permitted, which could go as follows:

$$
\begin{array}{rl}
(Cx \lor Ax) & \dashrightarrow (By \lor Dy) \\
Zx & \dashrightarrow (Cx \lor Ax) \\
(Dy \lor By) & \dashrightarrow Wy \\
\hline
Zx & \dashrightarrow Wy
\end{array}
$$

Nagel could have either of these reductions in mind (Kimbrough, 1979).

Weak type-type reduction may fail for two reasons: (1) when one or both of the sciences does not contain laws which can serve to perform the reduction; and (2) in the absence of proper bridge laws. A still weaker sort of reduction is what Kimbrough calls *limited type-type reduction*, in which all that is required of is that the types of the reduced science be derived from the types of the reducing science (Kimbrough, 1979).

Yet another sort of reduction is *token-token reduction* where individuals described in the language of one science are identified with individuals described in the language of another science. Being implied by but not implying other reductions just mentioned, it is a weak sort of reduction. In symbolic terms, its reduction functions or bridge laws may be expressed in the following way:

1. (for some x, y)($\underline{Z}$x.$\underline{A}$y.x = y)
2. $\underline{M}$ = (some x such that $\underline{A}$x)
3. $\underline{N}$ = (some x such that $\underline{Z}$x)
4. $\underline{N}$ = $\underline{M}$

where $\underline{M}$ is an individual constant of S2; $\underline{N}$ an individual constant of S1; $\underline{A}$ a predicate of S1; and $\underline{Z}$ a predicate of S2 (Kimbrough, 1979).

Section 1.3.16

Antireductionist Views Considered More Closely

All the above conceptual tools developed through reductionary efforts in the philosophical accounts of science at the level of theory and laws would expectedly produce their dialectical counterpart in the form of antireductionist views. These have evolved, expectedly again, in different branches of scientific activity, from thermodynamics, if you like and as we have seen, to psychobiology, the study of our emotional and/or mental life in terms or in the light of biological facts. But one of the most technical and evidently most "fruitful" antithetical discussions in philosophy have apparently been developed in the area of the relationship between physics, or the so-called physical sciences, on the one hand, and biology or life sciences on the other, with their resultant conceptual and formal-logical products.

My discussions in the coming sections will yield something more substantial, I hope, as related to what might seemingly be called a moderately, or perhaps balanced, antireductionist account. In the meantime, I will try to present certain basic conceptual antireductionist approaches to the issue of reductionism, some of which I have already mentioned in relevant passages above.

In his introduction to "Studies in the Philosophy of Biology", with a subtitle, "Reduction and Related Problems", Fransisco Ayala stresses the complexity of organization as one of the outstanding characteristics of living matter, and distinguishes three domains in which questions of reductionism arise - they concern ontological, methodological and epistemological areas (Ayala, 1974). For my part, I intend to discuss these basic distinctions in the related sections of the work later on and compare them with my related notions as I have treated them in outline in this introductory chapter.

Relevantly for us in this context are approaches to certain biological concepts such as cell, organ, species, genetic homeostasis, and so on, arising, according to Ayala, clearly from a definitional insufficiency in physicochemical terms in the current state of scientific development. Introducing the presentations of the participants to the above-mentioned work, he mentions two conflicting views discussed by G. Montalenti, one reductionistic and the other antireductionistic, that have existed since the most remote origins of biological studies. Among Greek philosophers, for instance, Aristotle had a holistic or vitalistic viewpoint, while Democritus advanced a mechanistic interpretation of life phenomena. However, if there is no need to introduce 'vital forces' or any other metaphysical entities in our time, principles not reducible to those of physics and chemistry are required to explain biological processes (Ayala, 1974; p. xi).

Section 1.3.17

Epistemological Reduction and the Clarification of the Terms

W. H. Thorpe, writing in the same volume, uses C. D. Broad's notion of 'emergence' in his arguments against epistemological reductionism. To be able to explain, in Broad's words, the behaviour of any whole, "we need to know the law or laws according to which the behaviour of the separate parts is compounded when they are acting together"; and the laws that explain the behaviour of the whole cannot be derived from laws explainig the behaviour of the parts (Ayala, 1974; p. xiii).

D. Campbell's general remark on the ambiguity of the terms "reductionist" and "anti-reductionist" when they are used without qualification to describe the position of a scientist or philosopher (Ayala, 1974; p. xiii) is evidently a point of highest conceptual importance in any serious discussion on the issue of reduction. And in a way, it could be the most significant background or step in our attempt to epistemologically clarify the concepts in connection with the relationship between physics and biology.

Section 1.3.18

The Classical Account of Theory Reduction as "the Received View"

Borrowing Putnam's term (1962) as related to the approach of the philosophers of science earlier in this century to scientific theories, in response to the developments of physics at the time, as axiomatic calculi which are given a partial observational interpretation by means of correspondence rules (Suppe, 1977), we may perhaps call The Received View on Theories those formulations of reduction centered around Nagel's original understanding of the problem. The antireductionist challenge, too, may perhaps be likened to those criticisms, beginning in the 1950's, directed to earlier interpretations of scientific theories and which may be roughly classified as partial and complete. But I do not intend to take the analogy further, nor will it be my job here to make a direct attempt to find real connections between reductive operations and the status of scientific theories in general.

In the case of biological theories, as we have seen, genetics has apparently been the most extensively studied area for reduction. The reasons for this interest in genetical theories to clarify the problem of reduction in biology generally might itself be made clear in the course of our discussion, even if not necessarily directly in all its dimensions.

"KINDS" OF THEORY REDUCTION IN THE PHILOSOPHY OF SCIENCE

An Incomplete List in Temporal Order

Particularly those which have been developed by certain philosophers interested in reduction in biology and/or whose work can be referred to for such a purpose.

- "Epistemological reduction" (W.H. Thorpe, [in F.J. Ayala] 1974);

- "Compositional and evolutionary theories" (D. Shapere, [in F.J. Ayala] 1974);

- "Intra- and interfield theories" (L. Darden and N. Maull, 1977);

- "Historical unification" (N. Maull, 1977);

- "Deductive preservation" (W. K. Goosens, 1978);

- "Reduction as a kind of deduction" (W. C. Wimsatt, 1979);

- "Successional and interlevel - explanatory - reductions" (W. C. Wimsatt, 1979);

- "Direct and indirect reductions" (R. L. Causey, [in D. L. Hull] 1981);

- "Intra- and interlevel - micro- - reductions" (R. L. Causey, [in D. L. Hull] 1981);

- "Homogeneous reduction" (K. Friedman, 1982).

Most of the above terms, in addition to certain others, have been mentioned and/or discussed in this chapter, while one or two of them will be considered in Chapter 2.3. The opposite of the last term, "inhomogeneous (heterogeneous) reduction", was already used by E. Nagel (Roll-Hansen, 1969), who is justifiably known as the first "formulizer", in 1961, of the two necessary and sufficient conditions which (allegedly) enables the philosopher to effect the reduction of one branch (or theory) of science to another - namely, the conditions of derivability and connectibility (Ayala, 1974; Beckner, 1974; and others).

Chapter 1.4

THE CONCEPTS OF MATTER AND THE PHYSICAL

In an attempt to clear the ground in the matter of reduction so far as our knowledge of the empirical world is concerned, it seems that one more point of general importance needs to be taken into account. The idea of matter as representing an all-penetrating entity is often confused, I think (and as has apparently been thought by not a few other people), with the notion of what is physical. Evidently, and both having spatiotemporal existence or space-time occupancy, the two intersect but do not coincide. In other words, they are similar but not identical concepts. From the point of view of the concept of levels which we shall consider soon, matter would represent the lowest level of organization in the empirical world, and thus form one of the very basic units of, and concepts in, physics. Matter is organized to form, so to say, the higher and complex levels of spatiotemporal existence and assumes different qualities thanks to, apparently, new relations and configurations, that is to say new forms or species of space-time occupancy. What is physical, on the other hand, (and for which I have no term in noun form in mind) is represented just by whatever exists spatiotemporally, irrespective of whether it belongs to a simple or complex level of organization; it thus comprises the whole gamut of the empirically possible or rather existent manifestations of matter. And it constitutes, in its various forms, the subject matter of all the sciences, from mechanics and subatomic physics to human psychology and sociology, so far as direct perceivability and indirect conceivability (as in the case of atoms or the subconscious) are concerned.

That a circularity would be established between the concepts of matter and the physical on the one hand and the notion of the levels of organization on the other seems to be almost inevitable, at least at the present stage of our conceptual approach to the problem of reduction. And what is going to be discussed in this section together with what has been pointed out in the introductory paragraph above would appear to be basicly of the nature of a preliminary sketch or departure point to be taken into account for the completion of the overall picture of our topic. Not unexpectedly, I think, the dictionary definitions of either term do not appreciably differ from each other, with the semantical core being constituted by "having the properties of occupying space and being known to us by our senses." Matter is defined as that of which the whole sensible world is composed and apparently as being equivalent to the older term "substance" and, also, as being opposed to what is called "mind". The adjectives "material" and "physical" both signify the quality of pertaining to or connected with nature, matter, or material nature, as opposed to being mental or moral (and, to mention a term rather outmoded in what we might call secular philosophy, "spiritual") and perceived by the senses; "material" also means, of course, "consisting of or related to matter". Evidently of particular interest to us in this context, matter is thought to mean "the substance of which a physical object is made," and also any "physical substance" not definitely particularized. And in a sense basicly of historical interest going back to Aristotelian ontology, matter would be that component of the "essence" of anything or being which has bare existence but which requires the addition of a particular form.

Though as a passing remark, we could relevantly point out to the authors of such dictionaries the inevitability now of the incorporation of the concept of time into any serious discussion of matter and its organization. But here we may leave the undertaking of a closer look at the issue to later chapters.

It must be rather apparent if not quite obvious that what is physical is related, for the most part perhaps, to the world of our senses, directly to the macroscopic world, and indirectly to its extensions into the microscopic realm. And as our visual power increases thanks to the development of optical and/or other instruments, our observational world becomes more and more enlarged at the expense of, so to say, its theoretical or not directly observational extension. In any case, that which is physical is either directly and observationally, or indirectly and inferentially conceivable and empirically analysable. In such a sense, **what is physical, or the "physical" as mentioned in the title of this work, becomes (almost?) identical with what is empirical (or the empirical).**

In the case of matter, however, and in its sense used in our context, the conceptual element in ontological-epistemological considerations evidently covers the whole empirical range, exhausting the possibilities of existence for any entity (and relation, and so on). It is ubiquitously present in the empirical world, and is indeed the substratum of this world. Although from being purely conceptual it becomes more and more empiricly inferential by means of mathematical formulations and/or conceptual models in theoretical physics, it is nevertheless the purely conceptual or presuppositional aspect of the term "matter" which seems to be in the foreground of its meaning.

Of course, what it is in more concrete terms that we seem to be entitled to call "matter" would not readily be explainable. It must be obvious, however, that what is meant would depend on the historical context and the related conceptual framework. More significantly for us in this essay and as it is essentially a philosophical and not predominantly scientific concept, it seems that we shall never be able to arrive, so to say, at a tangible clarity. It may be seemingly justifiable to compare it with the apparently worn-out and obsolescent if not altogether obsolete (philosophical) term "substance"; just like "essence" or "noumenon", I think, the latter obviously has certain historical-philosophical connotations, to discuss which here would evidently lead us to a serious deviation from our main course. Besides and not less importantly, we might well dispense with such terms simply because they would appear to be redundant and could make things more complicated rather than illuminating for us.

It seems to be justifiable to say that as the world's ontology will become more and more deciphered, so to speak, by scientific activity, purely philosophical concepts, with their predominant historical background and load, will have to be eliminated from our universe of discourse, the classical cognitive function of philosophy being totally taken up, ultimately, by science.

There seems to be one more point which may be regarded as being manifestly important in our context in this section. Although the lower (mechanical, atomic, simple molecular...) levels of organization (with the so well known exception of the subatomic level) reveal in principle a much more definite and clearer mathematical expressibilty than the higher levels, mathematicity appears to be a definitely ubiquitous property of the world - if a thing does exist, that is, if it possesses an empiricly or spatiotemporally qualitative reality, then it exists in a certain amount or quantity expressible in numbers and has one or more dimensions which are measurable. Thus, strong or high mathematical expressibility is no evidence for any (sort) of phenomenon that it should be conceptually more entrenched, so to speak, in our understanding of the world (although it would have more quantitative dependability in terms of scientific accuracy).

Likewise, I think, with axiomatization. You could as a rule axiomatize any coherent set of propositions, but that would give no conceptual certainty to a set with empirical import (an empirical set) and impart to our knowledge of it a higher degree of explanatory power. Axiomatization is a logically operational procedure and evidently not an explanatory device. Hence the weakness, I think, of the thesis that the more readily axiomatizable (or, for that matter, formalizable) epistemological formulations such as theories concerning lower levels of existence would possess an intrinsic superiority over those related to higher levels.

The relevance and importance of the last two points will be clear, I hope, in the course of our main discussion in the next part.

PART TWO

THE PROBLEM OF REDUCIBILITY IN LIFE SCIENCES

Chapter 2.1

THE CONCEPT OF THE LEVELS OF ORGANIZATION

Section 2.1.0

Introductory Remarks and Analysis

The general empirical, existential or ontological framework within which our discussion is taking place can best be expressed, apparently, by the term "world". Stated otherwise, the whole context that is covered by what has been termed "the levels of organization" seems to be exhausted by what exists and by what, interdependently, we think exists - the empirical, sensible world that we observe either directly, in an unaided way; or, in addititon, by means of tools or instruments, and which we "complete" by theoretical entities - those entities, properties, relations, steady states and processes which we have not so far been able to reach and which are possibly, at least approximately, not too different from what we have constructed for want of a direct access to them.

Roughly speaking, the world is in principle to be constituted by nature and the universe. As we are not in a position to consider definitely the "biosphere" or "biospheres" beyond the realm of the earth, however, we have to contend ourselves with living beings or living systems as we find them "here" (if not just "here and now"). Hence the term "world" would imply "our world" in, on and over the earth with its "living" (as well as "nonliving") components. And for the purposes of this essay, I see no reason why we should not use the term "nature" interchangeably with it.

Before taking a closer, analytical look at the organic or biological entities or systems and their comparison and relationship with the inorganic ones from the point of view of the concept of levels of organization and in the light of our dicussion on reductionism, we might perhaps consider different terms or term-like expressions used in the related literature, and which we might regard, apparently, as semantic equivalents or counterparts of the concept I am going to elaborate. This I have to do, I think, at the expense of presenting an apparently unduely long "introduction" to the chapter.

"Levels of reality" (Grene, 1974a), to begin with, appears to have a major drawback. First, the term "reality" seems to have, in our time, a strongly naive, perhaps even non- or quasi philosophical, pseudo epistemological connotation. Although, ontologically speaking, we have to be realists, I think, to the extent at least that scientific activity rests on the inevitable acceptance of a "real" world and because we base our framework of discourse on what scientific theorizing and research offer us, "reality" seems to take so much for granted the existence of the world that as a term it would fall short of, apparently, representing a genuine philosophical concept. Leaving aside our concern for linguistic form for the time being, the "level(s)" of ontological existence would possess, it seems to me, a higher degree of sceptically balanced semantical power.

The term "levels of existence" would certainly sound, philosophically speaking, as a much preferable term; it seems to me to be one with a real promise of entrenchment but for the fact that the term "existence" could mean different things to different philosophers, and for some it has become the departure point of their "school of thought" with strong subjective and apparently philosophically unaccountable connotations, in my view, as in the case of existential philosophy. And in general philosophical terms, the term "existence" seems to have too much entrenched and even coloured indeed, so to say, to have a satisfactory function in some areas of the philosophy of science such as ours.

The expressions "levels of reduction" or "layers of reduction" (Stolz, 1986) have the obvious drawback, I think, of having already the term "reduction", pointing directly to the critical and disputed question to be treated. And "layer", although it could seemingly be a substitute for "level", appears nevertheless to lack the semantical multidimensionality of the latter.

The term "organizational levels" (Grobstein, 1976) has obviously the same semantical status as the levels of organization and has apparently the economy and form that a scientific or philosophical term would in principle possess. They both relate very strongly to the inherent dimensionality and complexity of the underlying ontology. The "levels of organization" is expressive of the distance between different and/or consecutive states in the empirical world - it makes us aware of their existence with its emphasis on the term "level", while in the "organizational levels" the stress is apparently on the inherently complex relational aspect of the concept of organization. The second one has perhaps a rather abstract connotation whereas the first appears to tell us the compact nature of our framework of discourse.

Although the two may safely be used interchangeably for all academic purposes, and I may do so at least as a matter of style, my ultimate preference lies with the term "levels of organization", probably in part due to my own established usage of it since the very beginning of my interest in the concept.

Section 2.1.1

The Idea of Levels

By "level", we could mean, first and foremost, a horizontality - a horizontal, perhaps unspecified aspect of existence, and which might, and do indeed, suggest bidimensionality. In such an abstract sense, it obviously implies a horizontal state or condition, represented by a surface. However, regarded in the light of "concrete" instances or applications such as atomic, molecular, cellular, organ, biological or psychological levels, we should add a third dimension - height or verticality, the property based, apparently in more simple terms, on the idea of perpendicularity or having a perpendicular quality. Sometimes, too, this third dimension is in the foreground with a horizontal line marking its upper boundary, the dimensions of width and length, or the two-dimensional quality of having a surface, being pushed back.

From our point of view in this work, all the three dimensions of the concept of levels are important and interrelated or interwoven, so far as the concept of space is concerned, although the "third" one, height, may at first sight seem to dominate our conceptual framework in our context. It is the verticality of the united or combined, interrelated "concrete" parts or components revealing upward and downward arrangement that our concept of matter would be most closely related to our overall framework. The interrelatedly existing or organized matter would fill, so to say, the whole height of a level in question, atomic, molecular, or biological, with the necessary inclusion of whatever exists at the levels below. (It may be that ontologically speaking all the dimensions are on a par from a physical point of view as it was analysed in section 1.4, but that our "upward" biological organization and our corresponding relationship with our environment apparently puts the dimension of height in a different perspective.)

Section 2.1.2

Levels of Organization

As the above discussion would suggest, I think, and as we must be intuitively taking it "for granted" as regards our usage of these terms, the concept of levels does indeed appear to be indispensibly connected with that of organization, which gives to the former's analysis an empirical clarity or fullness, so to say, if not a complete content. It suggests, further, the interlevel relationship. Components occupying one or more levels would be interconnected and help form, as it were, tangible space-time occupancies. The additional idea of sublevels is evidently indispensanle, as we know that what could be called main or basic levels have a "thickness" and are brought about by those of lesser "thicknesses": subatomic particles, molecules of lesser size and complexity, subcellular organelles, organ systems, various functional layers of the brain, different levels of our mental life, and so on, as compared with the larger constructs they belong to. And the term "layer" might indeed be an equivalent, hence a substitute for "level"; however, I shall prefer the latter term here, as I have pointed out above, for its apparent comprehensiveness and entrenched philosophical usage; and, further, unless it becomes necessary for me to specify whether a given universe of discourse concerns a certain sublevel or several sublevels, I shall use the more comprehensive term "level(s)".

Our analysis of the empirical levels, including theoretical ones such as those brought about by the organization of atoms and subatomic particles (and not to mention their metamorphized extensions such as psychic phenomena), might imply three properties or rather aspects of organization which seem to be particularly important in a theoretical approach to the concept of levels. So far as I can see, these are unity or togetherness, coordination, and coherence, or rather perhaps consistency. The first implies structure, the second function (in the sense of non-accidental, systemic, or "meaningful", "organic" relationship among the parts of a whole), and the third one a continuity or extension or identity in time as well as in space. Taken together, all these characteristics and possible others would strongly suggest, in my view, the idea of system, a concept which I shall treat somewhat in detail in a later section of this chapter. The significantly relevant point in the present context seems to be that the concept of system suggests, immediately or at first sight, the notion of three dimensionality.

From a scientific as well as existential point of view (and whatever their philosophical status may be), we may say that wherever there are states of affairs there is matter, and vice versa. From a philosophical (and also scientific) viewpoint, states of affairs may be of two sorts - events which are specific and happen once and only once, such as my letting this thing fall here and now; and phenomena which occur again and again, in principle indefinitely perhaps, as in the case of the falling of anything in very different space-time settings. As on the present account, all states of affairs are related to different manifestations of matter at different levels of organization, and the latter may be said to exhaust the empirical possibilities in the world, as we know it, from a certain point of view; other, additional points of view, such as, and possibly above all, the idea of systems, would be needed for a "full" conceptual exhaustion. From such a comprehensive point of view, what matters would be a coherent unity, each part having a special function or relation and the totality of the entity being unified into a coordinated functional whole, most typically in the case of living systems.

Understandably, all the above points centered around the concept of organization have indeed a special relevance in the case of living entities which constitute the biosphere and where we find the first and foremost sense of the term "function". And the relationship between the idea of organization and the essentially biological term "organ" as the entity or part composed of several tissues and adapted to the performance of specific function(s) must be quite clear. For the general, philosophical purposes of this work, however, I shall as a rule use the term "organization" in an overall comprehensive sense as related to the concept of levels as a whole.

Section 2.1.3

The Earlier Thinkers of the Concept

Just as in the case of the recognition of the impossibility of trying to explain phenomena (of nature) outside the scope of a material basis, the exchange of matter and the circular relationship between the inorganic world, plants and animals (Béclard, 1862; pp. 6 and 10) together with the consideration of organized matter and the concept of organization (Béclard, 1862; p. 1) is not new and goes back to the 19th century. At about the same time in that century, we witness a more or less clear notion of the levels of organization (Littré and Robin, 1858; "maladie"), and earlier than that the idea that there exist three main levels of phenomena in nature, namely physical, chemical and dynamic (Broussais, 1829; p. 138). Further, and more interestingly I think, an author in the same century writes that to be able to make a definition of living beings, "it would be impossible to dispense with attempts to find a parallelism between them and the nonliving entities"; this had first been mentioned, allegedly, by Vicq d'Azyr (Robin, 1849; pp. 84-85) in the previous century. Still more interesting, I think, would be to learn that Avicenna, in the 11th century, mentions "organs composed of organized parts" (Krueger, 1963; p. 26), although, expectedly, not with the same force as we find, for instance, in the last century (Béclard, 1862; p. 6) when it seems to have "reappeared" (cf., for example, "Cours d'Etudes...", 1803; title p.).

Claude Bernard was apparently one of the leading figures of the same century who had a clear awareness of the concept of organization, particularly when he mentions "the organized anatomical components" and "the special organization of living beings" (Bernard, 1866; pp. 120, 143).

Section 2.1.4

The Contemporary Views of the Concept

In our time, levels of organization are mentioned or discussed apparently with increasing frequency in relation to reductionism or the idea of reduction. Not surprisingly I think, rather than in general or purely philosophical works you would find it in those of the philosophy of biology. It seems that unlike several other concepts and above all reduction and reductionism perhaps, there happens to be no appreciable controversy as to the basic semantics of the term "levels of organization".

Interest in it having grown rapidly, however, organization now forms a major theme in very many different areas, and the properties that characterize it are no longer regarded as typical or definitive of the living state. A collection or aggregate may become an organization "by establishing some functional relation between its components or units". It is not created "simply by the number or size of its elementary units but by the existence of the organizing or operational rules that define functional relationships between the units and regulate their interactions, "these integrating, operational regulations giving "coherence, integration, meaning, and purpose to the activities of the organization and define it as a distinct, recognizable entity." And "without such rules the units simply revert to the unorganized collection or happening" (Mercer, 1981).

The idea of the levels of organization, on the other hand, is a concept "arising from the possibility that a group of organizations may themselves become units of a higher level organization operating in accordance with its own rules and regulations." Further and further levels of organization would be created in this way which would lead to a hierarchy of levels of organization; here, "the organization at any particular level unites the units of the next lower level, which are themselves organized by the level above" (Mercer, 1981).

A further concept that would immediately come to mind at this point in relation to our main theme could best be considered, I think, in a separate section.

Section 2.1.5

Emergence

While developing his idea of organization, E. H. Mercer bases an implied notion of emergence, without mentioning the term, on his account summarized in the previous section. "Higher levels of organization formed by the addition of further restrictive conditions to an existing organization may cause a new function, a distinctive behavior or capability, to appear." The new organizational levels may be obvious and distinctive in natural systems, whereas in others they may be arbitrary to some degree or a matter of convenience. And while the units of an organization at a particular level would still operate in accordance with their own principles, they are subject, at the same time, to additional overriding constraints that establish or impose the organization of the level above. The principles in question are not necessarily related to or derivable from the properties of the units it controls or their internal operating principles, which means that the principles organizing an upper level are novelties not necessarily predictable from the level below (Mercer, 1981) (my italics). A description of hierarchies among sciences, on the other hand, is understandably related to discussions of reduction and novelty (Beckner, 1974) (my italics).

As must generally be known, biological phenomena are hierarchically organized and can be dissected conceptually and physically into subsets which are again dissectable into subsets, each having a reasonably integral set of properties (Grobstein, 1976).

The players of a game such as bridge, chess or football are each an organized whole, and a new organization of a "higher" rank (or level) is created by the rules of the game prescribing the functional activities of the players. Clearly, these rules, which are operating principles, are quite independent of the players, "who are themselves operating in accordance with other internally organizing principles (biochemical, physiological, etc.)" and who may indeed participate, at other times, in other organizations. "Furthermore, players may be interchangeable with others without altering the rules of the game" (Mercer, 1981).

Most importantly for us and as I shall try to further elaborate in later chapters in direct relation to our main theme, Mercer points out the vital implication of the above passages - the arbitrary or indeterminate character of the rules of the game and the impossibility of inferring them from the biochemistry, physiology, and so forth, of the players. Such a game has evidently an independence of the physical and other properties of the players except insofar as it accepts their limitations. "It may indeed be played entirely 'in the heads' of the players," and "as organizational principles these rules exist as something distinct and different - sui generis" (Mercer, 1981) (my italics, except the Latin).

I think we may readily assume that the incorporation of an evolutionary approach to this account would only make it much more clear and dynamically comprehensible, filling up the temporal gap and serving as a reminder of the notion of emergence, one of the cornerstones of this essay to be elaborated both in this and the next chapters. We have to treat this notion, here as well as in the chapter on Implications, in a more comprehensive manner, ontologically as well as epistemologically.

Before discussing the matter of temporality from a more comprehensive point of view, however, I might quote the well-known remarks of a philosopher on the notion of emergence. "An emergent quality," according to C. D. Broad, "is roughly a quality which belongs to a complex as a whole and not to its parts." For example, "if we want to explain the behaviour of any whole *in terms of its structure and components we* always *need two independent kinds of* information." We need to know, firstly, how the parts would behave separately and, secondly, what the law or laws are according to which "the behaviour of the separate parts is compounded when they are acting together in any proportion and arrangement". Broad then considers what he calls the simplest possible case. "We know that a certain tap, when running by itself, will put so many cubic centimetres of water into a tank in a minute. We know that a certain other tap, when running by itself, will put so many cubic centimetres of water into this tank in the same minute. It does not follow logically from these two bits of information that, when the two taps are turned on together, the sum of these two numbers of cubic centimetres will be added to the contents of the tank every minute." Because, in the first place, "it is quite likely that, if the two taps came from the same pipe, less would flow from each when both were turned on together than when each was turned on separately," that is, "the separate factors do not behave together as they would have behaved in isolation;" secondly, "if one tap delivered hot water and the other cold water, the simple assumption about composition would break down although the separate factors continued to obey the same laws as they had followed when acting in isolation," as "there would be a change of volume on mixture of the hot and cold water" (Broad, 1923; pp. 23 and 61-62).

Bertrand Russell, while considering Broad's concept of "emergent" properties, aptly summarizes his views and overall approach to the matter. "He holds that a mind is a material structure, but that it has properties which could not, even theoretically (that is, in principle), be inferred from those of its material constituents. He points out that structures very often have properties which, in the present state of our knowledge, cannot be inferred from the properties and relations of their parts. Water has many properties which we cannot infer from those of hydrogen and oxygen, even if we suppose ourselves to know the structure of the molecule of water more completely than we do as yet" (Russell, [1927] 1956; p. 293). (In the first sentence of the quotation, "...that mind is a material structure...," is a should be replaced, according to the main thesis of this essay, by one of the phrases has, or is associated with, or possesses a corresponding, as will be clear in the chapters to come.)

Interestingly, and relevantly, I think, to our present discussion, it is stated in a leading medical dictionary of the last century that the classification of diseases cannot be made on the basis of their physical and chemical characteristics only (Littré and Robin, 1858; "maladie"); in a later edition of this dictionary, and interestingly again in my view, this expression which apparently implies emergence has been omitted (Littré, 1893).

When we consider the ontological units in the light of the idea of levels in one of the following sections, I think that the question of what emerges or is emergent will be put into a clearer perspective.

Much of the discussion on emergence has been clouded, in the words of R. L. Klee, by a lack of agreement on what the appropriate "unit" of emergence is; these units have also been called "marks". While some workers refer to them as "characteristics" and others as "properties", certain thinkers assert that it is ultimately the laws that emerge (Klee, 1984). It thus seems that some thinkers see the matter as an ontological issue and others, depending on the notion of "law", as an epistemological or nearly epistemological problem. I shall discuss the problem from my point of view later on in this part, and consider it in the related passages to come and within the context of evolution in the related chapter of the Implications part of this essay, for evidently underlying the concept of emergence must be an overall temporal approach which can only be termed "evolutionary". In such inevitably or unavoidably evolutionary terms, the qualities emerging in the course of time are obviously not reducible to or derivable from which they have emerged. The full meaning of this observation is to be clearly understood following our discussion in the next sections on different aspects of the concept of levels.

Section 2.1.6

Temporality and Levels

I think that the reader would not expect me to say something, under this heading, about the "nature" of time on a supposedly very basic philosophical level. In a way, I have to take time for granted, so to say, and try to see the idea of levels in the light of the concept of temporality, although, to be sure, not necessarily in what might be called the common sense approach, the main difference of our approach from the latter being an expectedly analytical orientation.

Without considering the interrelationship between levels of organization, including the temporal one, to be considered in the following sections, the idea of levels and their organization would be almost meaningless, and without such a departure point or presupposition there could be no reductionary arguments and no antireductionist views as their dialectical counterparts.

Temporality in our context appears to be twofold. First, and perhaps as in the case of almost every other major topic of theoretical importance, this concept has an evolutionary aspect (as we shall have the opportunity to see in the Implications) - emergence or appearance of hitherto nonexistent properties and/or laws comes to the foreground as the development, in time, of new sublevels and levels occur. Secondly, and this is what would particularly concern us in the present context, for a relationship to occur between any two levels, however "close" they may be to each other, there must elapse, empirico-logically speaking, a certain "amount of time" because just as in the case of the causal relationship, an occurence at one (and as a rule higher) level or sublevel must be preceded by another occurence at a different (and in principle lower) level or sublevel, and all this in the setting of a flow which would be nothing else than what we call time. If this relationship would be one of interaction, then the direction or rather the sequence of occurences would on occasion be reversed, and so also the time relation between levels and/or sublevels. In other and perhaps more concrete terms, if the relationship between two levels of organization is to be seen as a process, which seems to be inevitable, as an empirical occurence it should have a temporal duration as well as spatial occupancy.

As a matter of basic principle and roughly speaking, a lower-level phenomenon would come earlier in time than its upper-level counterpart or homologue and would thus always precede the latter in the flow of phenomena. The feedback mechanisms, particularly so far as it concerns the living systems and takes the form of a negative feedback, will be discussed later on in this chapter. So far as simple temporality is concerned, we may say that once the reciprocal phenomena between levels are triggered, those phenomena that have a control over low-level ones must precede the latter when they are considered in isolation. In reality, and evidently because of the complex multilayer and bidirectional or reciprocal inter- and intralevel interactions, the functioning of the living systems must be very highly complex indeed. Considered at physical, chemical, cellular, and overall biological levels, the running of biped or four-legged animals, for instance, would be a good example with its reflex arcs as biofeedbacks.

As for the speed of phenomena in the course of all that happen, considered whether in an overall or partial manner so far as biological processes are concerned, I think that as a matter of scientific rather than philosophical interest this would go beyond the limits of our main topic.

Section 2.1.7

Mathematicity in Relation to Levels

The question of what lies below or rather what exists beyond the lowest level of organization, the subatomic realm, might be seen as a "metaphysical" problem in the sense that this sort of inquiry has apparently kept so many philosophers busy in their attempt to give an overall ontological picture of the world. But there would come a point at which the question of "what lies behind" would become meaningless, because, as Hans Reichenbach would possibly put it, there would be no "other" level of phenomena between which and the recognizably or imaginably smallest one we could find a connection or relationship. As in the case of an attempt to find a "cause" for the universe as a whole (Reichenbach, 1966), for instance, the most satisfactory expectation for an answer here would lie in trying to establish relationships between what can be observed and/or scientifically constructed and that which can be theoretically formulated (and certainly not speculatively imagined).

However, the above question in relation to our topic might be of interest to us, perhaps in an indirect way though, when we intend to discuss the relation of (pure) mathematics to the empirical world. Leaving aside, in a way apparently similar to the above approach, its consideration as an "ultimate" philosophical (or "metaphysical") matter, we may see <u>mathematical qualities of countability, measurability and calculability</u> within the hierarchy scheme of the levels of organization. If we number these levels, beginning with that of physics as level 1 and going upwards, as it were, and with sublevels to be labelled as 1a, 1b, 1c..., 2a, 2b, 2c..., and so on, then the subject matter of pure mathematics as a body of analytical propositions without empirical content could be termed <u>level 0</u>. I think it is no wonder that we would be at a loss to find a "concretely" ontological word (such as level) and could only use the epistemological term (analytical) "proposition" to express the products and conceptual tools of (pure) mathematical activity.

As for the mathematical qualities as part of the constituents or overall properties of the empirical world, we might perhaps encounter another though not a similar difficulty in placing it at the "0" level - the mathematical qualities of countability, measurability and calculability (the second of which would, I think, exhaust the properties of the traditional philosophical concept of "form" as well) concern or are related to all the empirical levels whatever the complexity of their organization or the related phenomena - if a thing does exist, that is, if it possesses an empirically qualitative reality, then it exists in a certain amount or quantity expressible in numbers and has one or more dimensions which are measurable (Örs, 1983); and if it would present a complex mathematical quality, such as we find in the flight of a fly or in any complex process in living organisms for instance, then it would need to be calculated by means of more or less complex mathematical operations.

From an everyday life or "common sense" point of view, or at first sight, we might perhaps say that "logically speaking", quality precedes quaintity, or that, in more concrete terms, the empirical quality of a thing precedes its quantity. In other words, a thing must first exist, seemingly, so that it could possess, derivatively as it were, certain mathematical qualities. In a certain analytical sense this may be true, because but for the empirical existence, or without the levels of organization for that matter, there would be no mathematical properties - that is, if no electrons and other subatomic particles, no atoms, no molecules, then no empirically countable numbers, no empirically observed geometrical forms and relations dependent on them. And further consideration would make it clear to us that this would the case for the ontological reality at any level of its organization - if no subcellular structures, no cells, no organs..., no individuals, no societies... then no mathematical entities, or rather characteristics, at the corresponding levels (Örs, 1983). In other words, if no levels (of empirical organization), then no level zero (of mathematical properties).

This seems to be in compliance with what was pointed out by Russell - we wrongly think that because a word is fixed and definite it must refer to something changeless and substantial; we do not take into account that, after the removal, so to say, of the attributes like its shape, weight, the matter which it is made of, and so on, a thing expressed by the word, say, "table", would no longer exist as something to be called as such (Wood, 1963; p. 58). Hegel, before, had also questioned this point (Hook, 1955). In the words of Russell (and in the language of an empirical logic if you like) there would be "no essence without attributes" (Wood, 1963; p. 58).

Relevantly in our present context, there can be no "mathematical phenomena" or "mathematical events", but only mathematical truth of pure mathematics on the one hand and the mathematical qualities of the empirical world on the other. The latter are parts or constituents of ontology in a very direct manner, while mathematical truth exists indirectly, necessitating the existence of "thinking minds" to be conceived, processed, developed and operationally enlarged.

The relationship, for instance, between natural, physical geometry and mathematical geometry can best be explained by pointing out by what Reichenbach has called coordinative definitions which transform abstract analytical statements of mathematics into empirical synthetic statements by finding the geometrical properties of the physical world. Between several "relative" systems of geometry, based on "convention", the different is not in their content but in the languages in which they are formulated by means of classes of equivalent descriptions. This enables us "to describe world objectively by assigning empirical truth to only one class of (such) descriptions". The relationship between the classes of geometrical definitions and the empirical world has been called congruence (Reichenbach, 1966; pp. 131-140).

We could possibly enlarge the scope of mathematicity here by including the arithmetical and algebraic, integral, and perhaps other properties in addition to geometrical qualities, of the empirical world, although operationally there could be significant differences in differing (empirico-mathematical) divisions. However, already in the light of the preceding discussion and possibly without closer analysis, the status of mathematical properties would ontologically be seen differently than in the case of the seemingly entrenched approach, and as being synchronic, so to say, with other qualities of existence. After all, they are among the constituents of the ontological units in the world, namely entities, properties, relations, processes and steady states, just like any other essential quality observable in the empirical realm.

Section 2.1.8

Levels and the Ontological Units of the Empirical World

It is the multidimensionality, a three-dimensional continuum with temporality as a fourth dimension, that we have to take into account in an analytic-semantical discussion on the notion of levels in the empirical world. The term "quality" I mentioned at the end of the preceding paragraph must be considered as related to the rather classical concept of "thingness", the state or rather the property of being a "thing" or entity. Classically, again, "properties" and "relations" have been considered together with "entities" and apparently with a view to conceptually exhausting that which exists. To complete the picture in a more comprehensive manner, however, we have to see them in the light of time, that is, from a dynamic point of view as well, as has been the case almost certainly in all the areas of science. The temporal gap, so to say, left by the traditional distinction of entities, properties and relations, is now to be filled by processes and their momentary counterparts, status quos or steady states - thus, although the non-stop flow of occurences and happenings would make it difficult for us to recognize them separately in the overall states of affairs, we do delimit them in time as well as in space, and make out the processes and break them up into situations or states of whatever (though not necessarily short) duration.

The point certainly needs to be illuminated by proper examples to give an overall and coherent philosophical account of all that constitutes the world's ontology. An aging person, for instance, as an entity with many properties and with his or her relations with the surroundings, undergoes change which is a process and which can be divided, for theoretical as well as practical purposes, into seemingly or, if you like, pseudo static steady states. I think these may all be regarded as different and dynamically ontological aspects of what we call phenomena or regularities, those occurences which are in principle repeated ad infinitum: atomic and chemical reactions, functioning of organs and organ parts, mental processes, economic states of affairs in human societies (and in the communities of other species)... Thus, although some remain relatively or seemingly stable for a certain period of time, entities do change, and similar and even (in principle) set-identical entities with similar or identical properties and relations reveal similar or "identical" changes and steady states.

Other universally ontological components or units may be "discovered" in the future, but I think that this would not change, in principle, their overall empirical (and epistemological) status and interrelationship- they appear to be exhaustive in principle with no need of a foundationalist approach in any philosophical universe of discourse. An entity exists, at one and the same time, with its properties, relations, its different steady states, and in terms of certain changes through time, thus assuming the quality of a process. Apart from all these, I can see no justification in conceiving any "fundamental" entity or "thing" or whatever, on which to base the whole of the empirical world, and which would seemingly assume the role of an "ultimate" constituent (of the speculative philosopher).

As for the relationship between levels of organization and the ontological units, this seems to me to be an issue that needs yet to be developed. Certain units or aspects of the empirical world, of reality if you like, such as processes and relations, have been mentioned in the introductory section, and more will have been said on the intersections of the two realms in the related sections or passages to come. Briefly speaking in this context, one might indicate that entities could be considered with their properties as they appear at a certain level; with their relationships or interrelations at different levels; as steady states at their own and related upper and lower levels; and constituting processes, as different entities at different levels occur interdependently. One might also point out that in most general ontological terms, empirical reality can be divided into two different though inevitably interrelated constituents: structural or existential and relational or dynamic. Roughly speaking, the former group has a quasi static ontological status, its components and overall composition being only seemingly unchanging. As a rule they constitute the objects, existing things or existences, material entities or beings. They are the units of existence in the world: a tree, wood, ants, a human being, the human society or animal communities, cities, nests, and so on and on. At the theoretical level, we have atoms and subatomic particles, molecules, "genes" and other entities not directly observable. On the other hand, relational kind or aspect of reality is, prima faciae, dynamic, representing the connections, so to say, between entities or beings. Their existence seems to be, at first sight at least, of a somewhat dependent or derivative and less concrete kind. They relate entities in the form of loose or tight connections - atoms and their parts, systems of living organisms with their interrelations, living beings and their environment, individual human beings and the societies they live in, and so on. In reality, every existence appears to represent, in the final analysis, a process; and considered temporally, entities too would assume a dynamic character - a decaying wood, a growing plant or child, an aging animal, the changing society, the worn-out rock... (Örs, 1984).

We could perhaps add a last point in this section in connection with one of our main topics - emergence. We may remark, I think, and although this would apparently bring no real dynamic or explanatory force to the idea, that new entites, properties, relations, steady states and processes appear or come into being in the evolutionary flow; and when this appearance or coming into being shows substantial difference as regards the already existing overall component units of the world, we would be in a position to talk about the birth of a new level or sublevel of organization.

Section 2.1.9

The Relationship Between Levels of Organization: Parallelism or Correspondence

Even for a "strict" reductionist, it would not be possible, evidently, to disregard the relationship and not to "see the distance" between the levels of organization. Because, otherwise, what could be reduced to what in any coceptual and/or philosophically operational sense of the term? In other words and more generally, the "reduction" of one or more levels to lower ones would certainly imply the existence of such relations - reduction in an epistemological sense is an expression, to whatever extent it may be realized, of this relationship in the ontological realm. On the other hand, even from a strong "antireductionist" point of view, too, such a relationship would clearly be undeniable, provided that an unscientific element, for instance a vitalistic principle in biology as a scientifically redundant factor, should not be introduced into the universe of discourse. Unrelatedness between levels would imply an epistemological vacuum, a nonconnectibility from both a scientific and, in an inevitable and realistic sense of the term, philosophical viewpoint. An unrelatedness between the world of atoms and (simple) molecules on the one hand, and cells and organs on the other hand appears to be no longer tenable - the issue would seem to be one concerning the history of philosophy (and also, of course, of science).

This relationship has been variously called, "epiphenomenon" being perhaps the most historical one; and the terms "parallelism" and "correspondence" seems to me to be the most suitable ones for our purpose in the present context. Apparently, the latter term has a more recent history and could possibly be preferred, in the light of our modern scientific approach, to earlier "philosophical" terminology, particularly within the context of the reduction-antireduction controversy. "Parallelism" appears to imply, possibly with the addition of its historical connotations, a rather moot or loose relationship; it might even denote a non-regular, non-reciprocal if not accidental "relation", as was apparently the case, for instance, in certain arguments related to the so-called "mind-body" problem (not to mention the "duality" question). "Correspondence", on the other hand, does not seem to leave any serious doubt as to the definiteness or tightness of a relationship or connection between different groups of entities, properties, and so on, belonging to different levels of organization. Without the acceptance of such a close relationship in the empirical world, the concepts we have discussed earlier such as organization, emergence, temporality, and those concepts we shall consider in connection with our topic, such as causality or function, could evidently be dispensed with following a rather short treatment. In this essay, on the other hand, and mainly for stylistic purposes, I might sometimes use the term "parallelism" (or one of its etymological relatives) more or less equivalently to "correspondence".

I think that whatever one's basic stance might be in the matter of reduction in our time, one should see the inevitability of considering together the idea of the levels of organization and the concept of correspondence; otherwise it would be meaningless and idle to treat the matter of reduction in empirical domains in general, and in the realm of biology in particular - an unrelated ontology would mean the disintegration, and an ultimate collapse, of a conceptual, methodological and operational unity between different fields in life sciences (as well as in the so-called physical sciences), cellular biology, biochemistry, molecular genetics, virology, and others. One would also state, justifiably I think, that correspondence is a "necessary empirical condition" in the relationship between the structure (of a cell, part or organ) and the function (of that "corresponding" structural unit). <u>Structure implies</u>, in the light of the network of the theories and data of modern science, <u>organization</u>, whereas <u>function is a specific kind of relationship</u> (this is in contrast to <u>disorganization which is destruction</u>, <u>dysfunction</u>, <u>decay</u>, and ultimately "<u>death</u>"); both concepts, from an evolutionary point of view, have been entrenched within an increasingly complex and dynamic conceptual framework.

The relationship between levels is certainly very highly complex, multidimensional and reciprocal. To stress the point again, so different phenomena (or subphenomena) take place in the realm of life whenever a certain apparently single but actually very complex phenomenon occur at the level of biological organization - when, for instance, blood is pumped by the heart and sent into the blood stream during the systol, the whole cardiovascular system shows great alterations, as compared with the diastole which is the resting state, and this at the physico-chemical, subcellular, cellular, tissue and organ levels, and when the neural, muscular, and connective tissue elements making up the system undertake, and "share the responsibility of", the functioning of this system as a whole. No less complex change and phenomena are to be expected, quite evidently, in the realization of any important and complex activity taking place in any multisystem form of life - digestion of food following a meal, detoxication of a hazardous substance by the liver, growth of tissues and organs due mainly to the activity of the endocrine glands, perception on the part of any sense organ and the related part of the brain, fecundation of the ovum by a sperm... In all these, the complexity is contributed to by the control mechanisms at different levels of organization, above all by circular control or negative feedback (as we shall see in some detail later on).

Correspondence would mean, in our context, the parallel occurence of a set of phenomena at two more layers and/or sublayers of (a certain kind of) organization in the empirical world. Our earlier discussion on temporality and levels must have contributed to our understanding of the correspondence of levels - the time lapse between the subsets of corresponding or related phenomena would imply that they could not, in a strict sense, be synchronic or temporally co- existent.

In a dynamic or temporally more satisfying manner, we could preferably speak of **corresponding processes at different levels**, and certainly also of relations, and so on. The consideration of processes and other ontological units as possibly exhaustively constituent parts of occurences in related levels would of course make our discussion on levels of organization much more complex, as we shall see in later sections and in the next chapter. This point will also be an important topic in our discussion on causality and levels in the coming section, with an overall integration to be realized in the last section of this chapter.

A topic relevantly to be considered in the light of the correspondence between levels of organization is the relation of mathematical qualities to the latter, which we have already seen in a previous section (2.1.7). From the viewpoint of correspondence between levels and as an issue to be clarified, the near motto, "accumulation in quantity leads to change in quality" appears to be an undue, superficial oversimplification; it seems to reflect an uncritical and too distant a look at the related states of affairs. A seemingly better and conceptually more satisfying formulation of it, in terms of dialectical materialism, is that "gradual alterations in the quality of something are not necessarily accompanied by a merely gradual alteration in its characteristics". By "gradual alteration(s)" is apparently meant, in this context, a mathematical or rather mathematically expressible quantitative change. But what really matters here is that underlying this mathematical expressibility is an empirical existence, or the existence of a level of organization, because as there can be no mathematical property without an empirical existence, quantity cannot be thought of separately from at least one level of organization - be it that of matter or any other level (if we keep apart the evolutionary considerations in which we should first take into account the former). "Quantity" as an abstract, pure, analytical concept cannot be thought of as having a potential to produce "anything" in the empirical world as there would be no transitivity between the two, but only a togetherness without any duality or, better still, distance; hence, no parallelism or correspondence between the empirical levels and pure mathematics can be said to exist. Instead, we could justifiably speak of (the) congruence, to mention again a term proposed by Hans Reichenbach to express the relationship between geometrical definitions and the empirical world (Reichenbach, 1966, 131-140), this time, however, using it in the overall context of mathematics.

When quantity depends, empirically speaking, upon a certain level of organization, then the principle of correspondence would require another level for an effect or connection to occur between what produces and that which is produced. In other words, and irrespective of whether or not a mathematical property is to be taken into account at this stage of analysis, there must at least be two levels (which may also be equivalents of actual sublevels) of organization for a correspondence to occur, and correspondence appears to be the very basis or necessary condition for a change at one level to be caused by the related one at another level. And this would explain, at a philosophical level, how a quantitative change at one level would lead, expectedly in a cumulative manner, to a qualitative change at another one - as exemplified, for instance, by the diabetic coma as a result of high levels of blood sugar; the educational quality of a course contributed to by an optimum number of students; or by a riot caused by a constant or near-constant shortage of food supply and possibly other basic necessities. (In all such examples, the resultant change, too, has certainly quantitative [if not necessarily measurable or mathematically expressible] as well as qualitative aspects.) The two-related pairs of levels in these instances are biochemical-biological, social (in a small group)-intellectual, and biological(-economic)-social. In short, mathematical values can be considered, in connection with qualitative changes in the empirical world, only in relation to the levels of organization, and definitely not in an analytical vacuum, so to say.

Section 2.1.10

Causality and Levels

The relationship between levels would imply that there must be a close and "organic", tight connection, a rather firm tie involved; otherwise, we would be in a position to refuse the existence of corresponding or parallel phenomena or regularities occuring in a time sequence, however complex and difficult to establish it may be. This is what I have already called an empirical necessity. Considered in the light of our discussion so far, and particularly in that of temporality, such a relationship could denote a kind of determinism, hence also a causal connection.

Such a connection would be more difficult to describe as compared with the part-whole (actually part-whole minus part) relationship as is frequently considered in the matter of reduction, particularly in the light of the systems approach. This must evidently be due to a basicly concrete or comparatively "unextended" space occupancy of a system - even when it is not directly here (and now) with all its components observable, any system, even the universe or a complex living entity, is in principle "visualizable", however dimly this may be (see section 2.1.13). Comparable to the parts of a system would perhaps be the corresponding, empirically conceivable pieces between levels.

The concept of system is linked, I think, with the idea of structure - that of construction, or the coming together or evolving of pieces or parts to form a whole with more or less causal relations between them. The notion of levels, on the other hand, would best be made clear by the idea of organization, whereby a structure is expected "to enjoy a degree of stability and endurance" (Mercer, 1981). This is a deterministic consideration, for a regularity is thereby expected to be identifiable in spatio-temporal terms. Determinism becomes meaningful in the light of the principle of causality, because the former is the application of the latter in the form of the predictability of events (phenomena) (Bourquin, 1952). In other words, determinism is the extension of causality, that nothing happens without a cause (in its strict formulation), into future occurences. To put it in a somewhat different way, determinism would very strongly imply that causality as a principle of the empirical world would be valid in the future as well as at present (and in the past).

Causality and determinism in the context of levels would imply, particularly from the viewpoint of reductionism, that lower-level occurences precede and become the cause of, or determine, the corresponding upper-level phenomena - for instance, enzymes as biochemical structures determine, that is causally lead to, biologically meaningful phenomena such as growth, repair, digestion, intoxication, and so on.

Correspondence or correlation may also be looked at from the standpoint of regularities, that is in principle incessantly repeated or repeatable occurences. If there exist correlated entities and phenomena between different levels which present themselves as regularly observable occurences, and if there appears to be a constant unidirectional time sequence involved, then we would evidently be entitled to talk about a causal relation between what has happened, "organically speaking," at two or more levels.

This consideration apparently brings in its wake two more points among possible others. On the one hand, and evidently particularly in sociology, psychology, or higher-level biology (such as the functioning and dysfunctioning of organs in advanced multicellular organisms), we have multiple causality - those contributory factors and more loosely connected general conditions that would be relevant, for instance, in infectious diseases; mycobacterium tuberculosis is the causative agent, or the necessary cause of tuberculous infection, but without certain individual factors such as the relevant characteristics of one's genetical makeup and/or the vicissitudes of one's family history, and the adverse socioeconomic conditions in one's milieu, that is "under normal conditions" or, conversely, without sufficient conditions, tuberculosis would not as a rule develop in a human being. On the other hand, one might perhaps ask the question whether there could be omitted levels. We might treat the point in the next chapter on the relation of the biological to the physical level. As a matter of principle, however, I would admit that I am not so clear about the issue although my intuitive answer would be "no"; that is to say, no intermediate level can be omitted in ontological (hence epistemological) terms. This might be touched upon, also, in the last chapter where we shall have the opportunity to discuss the issue from an evolutionary perspective as well.

In any case, and considered from a general perspective in this section, if correspondence between levels is to be seen as a congruence relationship, as Reichenbach uses the term in relation t,o geometrical (generally speaking, mathematical) qualities of empirical phenomena (see section 2.1.7 above), then the causal quality of the relationship between levels (if not at all levels or between all sublevels) seem to imply strongly a causal connection in the form of temporally (apparently) coextensive and empirically relatable regularities. The principle of asymmetry involved in causal connection, too, seem to be supported by the imbalance between levels, at least due to the quantitative difference in organization which is sometimes great indeed, as in the case of the relationship between a high-level complex organism and its simple molecules.

Consideration of the notion of levels together with empirical principles in nature other than causality and determinism, such as indeterminacy, chance or dialectics, would take us too far away from our main course without, possibly and so far as I can see, any appreciable contribution to our main theme.

Section 2.1.11

Simultaneity, Identity and Coincidence

If I mention at the very beginning of this section expressions such as "temporal identity" or "identity (preserved) through time", the reader would be reminded, almost to be sure, of one of the main or "traditional" issues of philosophy - that of sameness or identity. Considered concisely, the problem is whether, or rather to what extent, an entity, changing in the course of time, would be seen as being identical with, or at least very similar to, its original or earlier forms - is the old man the same individual as the (corresponding) child or even the adult? Is the professor the same person as the (corresponding) student of so many years ago? Or is it the same tree which spatially occupies the same (or almost the same) place as the seedling.

But the term "simultaneity" may seem somewhat out of place, mainly because, possibly, the concept of identity has not been treated, as a rule and so far as I am aware of, in connection with this notion. However, in the light of space-time occupancy and the idea of levels, I think that a relationship can relevantly be established.

The temporal dimension of identity would come to the fore, it seems to me, when we examine the structuralist consideration of a more general kind of relation which they identify as being synchronic (or co-temporal, if you like); structuralists believe that synchronic relations are fundamental in a structure. At times, however, they speak of "structural causality", and as causal relations are diachronic (or temporally apart), and not synchronic or cotemporal, these two views seem to be contradicting each other (Puterman, 1980) (italics mine).

If we introduce the idea of levels into our considerations at this level of our discussion, it would greatly help clarify, I think, the connection between identity and simultaneity. If we would take the identity sufficiently strictly, in the way Leibniz considered it for instance, and for all theoretical as well as practical purposes, the "identity relation" becomes, or perhaps rather leads to, one of replaceability. However, in a stricter sense still, such a relationship could be seen as an inevitable coincidence with no room, by definition as it were, for an exception within the framework of space-time occupancy. Any entity (and property, relation, steady-state and process) becomes "identical with itself", nothing but itself, and can become nothing else. This would certainly be regarded as an awkward assertion, the expression of an untouchability, so to say, of any ontological unit, in which case, as a consequence, we would not be able to recognize universals ontologically, if we may use such an expression, and to formulate them epistemologically. In such a situation, there would be no connection between similar and sometimes "almost identically similar" particulars. When any two very similar or almost identical existences do not coincide with each other, then, speaking empirico-logically, their space-time occupancy should be different - they cannot be strictly identical, because either temporally or spatially, and so far as certain characteristics (such as colour, mass, and so on) are concerned, they might differ, to whatever a small extent it may be.

It must be clear that in an overall and strict sense, simultaneity, identity and coincidence are very much related. The existence of just one of them in the empirical world seem to necessitate the other two. The strictness in this context is evidently due to an analytic-formal philosophical treatment of synthetic propositions concerning the empirical world, which inevitably express spatio-temporal characteristics, differently from the atemporal, non-spatial, abstract or pure (that is, non-empirical) mathematical and logical entities. At what we might call an intuitive level at least, one could perhaps remark that the contingency of the empirical world would not be reconcilable with an almost analytical simultaneity-identity-coincidence togetherness - the latter would represent an unchanging Parmenidian world, evidently an impossibility.

Temporal continuity in the empirical world, which is represented by its preservation, is only possible, and thinkable it seems to me, in accompaniment with change, that is the attainment of a non-identical stage, and the same can be said of the relation of change to, or its dependency on, continuity.

The ongoing discussion would lead us to an inevitable loosening of the concept of identity, which must have been done already by so many others. When identity is taken to be close or very close to similarity, or to being identical nonsimultaneously hence not being coincidental, then it is empirico-logically possible to treat as one category all the particulars of an empirical set - carbon atoms, human DNA molecules or chromosomes, erythrocytes, livers, adolescents, communities, species... It must be clear that the higher the level of the entity, the farther is the distance between the strict identity model and the similarity relationship within the set which the entities (and/or other ontological units) form.

The introduction of the idea of vertical organization into our discussion would put the distinctions between different entities (and other ontological units) at different levels in a concrete perspective so far as the three main concepts of this section is concerned - the distance between two or more levels (and/or sublevels) implies a temporal relation, that is it signifies a difference in temporal dimension so that simultaneity in a somewhat strict philosophical sense would be out of question. The problem of identity could be seen differently or not depending on the relationship of the ontological units at two or more different levels, as the change at the lower level(s) would lead as a rule to change at the upper ones; the strict identity would not be defendable once we take into account the change in the empirical or ontological units of existence. As for the idea of coincidence, our very analysis in the light of the concept of levels would imply that the spatio-temporal distance between the levels of organization makes it impossible for any two related entities to coincide with each other, just as in the case of (particular) entities (and other ontological units) in the world at large and without any recourse to a detailed analysis of levels.

The most important corollary of the above discussion seems to be, so far as I can see, threefold, whereby certain already clarified points would apparently become supported and thus more entrenched in our related conceptual apparatus. One is that it stresses the fact that it is not only entities that we should take into account as ontological units - not even the addition of properties and relations would suffice in our discussion, but we have to consider the steady states and processes as well. Secondly, it must be clear that all these five ontological units should be considered from the point of view of the concept of identity. Lastly, "identity" becomes a philosophically dynamic and operational concept when we loosen it and accept as valid not the token but kind (or type or set) identity which would imply a more or less strong similarity relationship between its elements, depending on the universe of discourse, or on the ontological properties of the sets established or to be established, and at bottom on the balance between the similarities and differences of the sets in question. This would be more in conformity with a basic science approach because science so understood deals with phenomena which are universals, in ontic as well as epistemic terms, and can be equated, in contrast to (what is called) applied science such as clinical medicine, with "kinds" rather than single events which are particulars and can be seen as tokens.

The concepts mentioned in this section, particularly synchrony (simultaneity) and diachrony, could make it necessary for us to discuss them in the light of the principle of relativity, too; for they strongly imply, and should expectedly so imply I think, the presence of an observer and different points of reference. As this matter is not directly related to our main topic, however, we can very well dispense with it altogether in our context.

Section 2.1.12

Structure and Function in Relation to the Concept of Levels

The evolutionary biologist Julian Huxley draws to our attention the fact that the level of organization reached by the biological sector in nature is almost infinitely greater, though its spatial extension is very much restricted, than that of the inorganic sector in which the only overall tendency so far detected could be summarized in the Second Law of Thermodynamics, that is the tendency to run down (Huxley, 1963; pp. 14-15). In terms of this law indeed, the passage of time in the universe at large (at the lowest level) is marked by an increasing state of physical disorder or randomness, and while the physical universe is drifting into greater disorder, the essential property of life is that it is opposed to this current by imposing greater order from moment to moment (Bronowski, 1968; p. 124).

Viewing life as a whole, it wins its victory (so to say) over entropy through the principle of self-duplication, as if death of the individual was the penalty that life had to pay for violating the second law of thermodynamics; this is the principle which appears to be valid, at least theoreticly, for closed systems as in the case of the inorganic structures and not for the living entities which are open systems (Gutman, 1964; p. 12).

At all the levels of organization that the living entities possess, the structure and function appear to be interdependent. In evolutionary terms (and although we shall discuss the point in some detail later on), we may say that the processes that we call function have established themselves, so to speak, as repeated phenomena at certain levels and within the context of, and dependent upon, a certain kind of organization or structure. But first we must make clear what we mean by the term "function".

It does not seem to be an exaggeration to say that what matters in the activities of living beings in the last analysis or in general biological terms (both at the individual and group and/or species levels) is their relation to their environment, or their relationship with the environment, physical, biological, social. Furthermore, relationality in life is certainly no less important in the case of subsystems of organisms, namely organs, cells, subcellular parts, biomolecules and so on, than so far as individuals and groups are concerned. Indeed, we have developed our concept of function thanks to our evaluation of these relationships. Not all such relationships, however, can be called to be "functional" or can be seen as "functions". Anatomical relations or relations of macroscopic (and sometimes even microanatomical) neighbourhood appear to be, not infrequently, non-functional, and from a physiological point of view they may be taken (disregarding their embryonic-fetal developmental origin and relationships) to be an "accidental" kind of relationship - the anatomical togetherness of the spleen with either the stomach or the pancreas is evidently of no functional significance, just as the microanatomical joint location of the two functional parts of the pancreas, one being related to digestion and the other to sugar metabolism. And, in the opposite direction as it were, functionally related organs may be quite apart from each other with no anatomical relationship among them, as in the case of the endocrine glands, which have been dispersed in the organism and which form an overall functional whole directed to the growth, functioning and maintenance of the organism. In other words, anatomical relations in the form of contact, at least closeness or coextensiveness, being together in the same region of the organism, need not, at least not necessarily, to be taken as implying a functional relationship.

As a special sort of relation, or relational phenomena if you like, function must possess at least one essential difference or differentia, which should certainly be included in its definition. In our general context and borrowing a term from social sciences, a given function would be seen as an empirical necessity arising from the division of labour within living systems for which a certain, specific kind of structure should be available. One could fairly justifiably speak of a structure-function parallelism or relationship in which the former would apparently represent, ontologically speaking and apparently, an "entity-steady state pair" while the latter "the relation-process aspect" of the states of affairs in living organisms. Thus, at first sight at least and as I discussed earlier as well, structure is basicly a static and function, by definition, a relational or dynamic concept. And so far as the totality of a functionally (or "purposively") working system or entity in a given milieu is concerned, it is the function as the relational aspect of reality which has evidently a more direct significance.

Function, as a relationship and activity of a part within a structure or whole, may perhaps be regarded, by way of a teleological expression, as what a part or substructure "owes" to other parts or structures within that whole as a result of the division of labour. In more technical terms, this would be expressed in remarking that functions (of the parts) would constitute parts of the boundary conditions on the same and lower levels, set up by the emergence of a new level or sublevel of organization. The heart's pumping the blood into the circulation through the vascular system is a boundary condition, I think, because it controls, and is also contolled by, a (very complex) set of circumstances or phenomena without which the overall structure in which the system takes place would be unthinkable. If function is an action on the part of a given substructure at a certain level of an organized whole such as a living organism, then functions are interactions at different levels with the final effect on that organism as a whole. And if it is through coordination that the integration of a structure is achieved (Mesarovic, 1970), then function as coordination should be seen as the main or most significant set of relations that keep the structure together with its varied levels and depending on their number.

In our time, even if the developments in atomic and molecular physics are (or rather thought of) within the scope of morphology, the reborn morphology of the 1940's moved from physics to molecular biology; and on the fine structural level, structure and function merge, just as the normal and the abnormal, or the principles commom to man, animals and micro-organisms. These developments have obviously tightened the unity of biology (Popper, 1969).

Section 2.1.13

The Concept of Levels and the Idea of Systems

Leaving aside the temporal dimension for the moment, I think we must consider here the combination of systems and the levels of organization as being one of hierarchical integration and unity of the whole. In structuralists' terms, the emphasis would be on the idea of structure covering most of what could be meant by "organized systems" (Mercer, 1981). Organization in such a three- dimensional context would indeed signify wholes and subwholes formed by the integration of certain constituents, as a result of their coming together, structurally and functionally, in an empirical, space-time setting.

We might, and I think we should, make a distinction between an ontological and an epistemological approach to both levels and systems. Apparently due to its comparatively more conspicuous compactness with rather conceivable boundaries in principle, a system is, I think, a spatially hence ontologically much more definable if not necessarily directly perceivable entity. It is indeed an entity, however complex the structures and internal relationships of certain entities, such as living systems, may be. In the case of levels, on the other hand, it seems to be rather difficult even to visualize let alone recognize a "section" of reality, so to say, because of the seemingly boundless extension, above all on a horizontal plane, of many entities. But we do consider levels and their concrete constituents as mental constructs as regards the empirical world, that is to say, epistemologically. It may be said I think that relationships implied by the idea of levels primarily depends on an extendedness over an area, and not, as in the case of systems, on a more or less definable space setting.

Thus, while even a certain definable level is difficult to locate mentally, so to speak, because of the minuteness of the entities as we go down the scale and because of the inevitable connection or relationships between adjacent levels, a system apears to be a readily conceivable and sometimes even perceptibly demonstrable entity. However, such an approach seems to have a certain drawback or limitation, just because, possibly, our expectation of an overall entirety or perfect wholeness in the case of systems is so high. This makes the concept vulnerable - when that expectation of completeness is met with seemingly little empirical justification, that is if no causal or comparable relationship between the parts of a supposed "system" is established, we would apparently be in doubt as to its very existence. The astronomical constellations, for instance, with their analogical names but no organic relationships, so to speak, between their "constituents", the stars, form or rather give the appearance of a certain "system" when looked at and observed from our human reference, that is a certain point in our "solar system". Evidently, and scientifically speaking, they have no ontological, non-anthropocentric existential significance or existence in the universe; in other words, they are not true systems. It seems that in our context they might at most be considered as quasi or pseudo systems.

Two other ontological units of the world, properties and processes, could also be mentioned at this stage of our discussion; the former would be more closely related, at first sight at least, to organizational levels, while the latter would rather be related to the notion of systems. In evolutionary terms, above all, new, emergent qualities would mean new levels;

however, and not to exclude the fifth ontological unit, namely steady states, newly appearing existences in the form of emergence evidently represent all the ontological units, because the latter seem to be so "intimately", inseparably interconnected.

The evidently significant and interesting point which should be stressed appears to be that a system, to whatever degree of internal sophistication and in however a complex manner it may be related to the external world (that is to other systems), possesses a basic individuality. A level on the other hand, in whatever simplicity (that is, however small in dimensions) it may be related to other levels of organization, would represent a complexity and, in an interestingly contrasting way, an overall diffuseness or extendedness.

It must be clear that in an overall manner systems and levels of organization are, far from being mutually exclusive, interdependent and complementary, apparently both ontologically and epistemologically. Hence a need, from a conceptual point of view, for the unification of the two notions and for seeing the problem of reduction in this light as well. In a conceptually extensional way, so to speak, this togetherness covers the whole area of empirical existence, composed of the total volume of a level (or levels) of organization plus all the systems as structures with their parts within that level (or those levels). Even when taken singly and depending on its complexity, a system can be said to comprise different levels at which it has been organized, though it is conceptually much more concrete and tangible, with a delimitable space (-time) organization.

Lastly in this section, one more point may be added to the topic of levels and systems being considered together. Any subsystem (and system) may be placed at a certain level of organization; or, conversely and I think more truly, any structure at any given level stratum can be regarded as a subsystem (or system). In all this, however, consideration of the interactions in the form of cross-strata interdependence appears to be inevitable for a complete understanding of the system (Mesarovic and others, 1970; pp. 30-33) and the levels (my italics). We must consider the combination of systems thinking and the conception of levels, to put it again, as being one of hierarchical integration and unity of the whole.

Section 2.1.14

Complexity, Relationality and Levels

The apparently elusive nature of a philosophical discussion on the ontology of the world would assume more and more a circular character, I think, because the ontological units of the world appear to be, with the proviso "as far as can be said for the time being", not independent but jointly and exhaustively complementary, leaving no gap behind in the overall empirical realm. In a significant sense, they seem to be different aspects of the same reality in a complex space-time setting, a reality which we cannot name outside the scope of the ontological units of entities, properties, relations, processes and steady states, just because, apparently and so far as we can conceive, there would be no other way to approach this core except through one of these units. If entities represent somehow dense cosolidations of matter which we know through their properties, they are then in relation with other entities as are their parts internally, and are dependent on the flow of change in the course of time with resultant processes covering all the other four, quasi independent ontological units.

We have already discussed these and similar points, in slightly different contexts though. The point may be stressed here that except a comparative analysis of such general concepts as matter and the physical for instance, a "metaphysical" basis for ontology appears to be doomed to failure, for such an unchangeable, seemingly "given" solid basis is unreal and, scientifically speaking, virtually nonexistent. The same relationality and interdependence can be said, we must add, of such concepts as regularities and uniformities, discussed by the philosophers of science, and phenomena and systems as they are used by scientists. In actual fact, they represent, apparently in differing degrees, the qualities of generality or universality, existentiality, continuity, temporality (and possibly similar concepts of philosophical interest). Again, and from a slightly different perspective perhaps, these too form an ontological whole (if not a totality) and are representatives of that whole.

My reason for discussing these concepts seemingly at the expense of an apparent deviation from our main course is best expressible, I think, in the concern for a total accountability of the ontology of the world for our conceptual-epistemological analysis of the problem of (a certain kind of) reduction in science. Whether all the above considerations would be relevantly and successfully, though sometimes indirectly incorporated into the idea of levels will certainly be clear in the course of our later discussion.

I think that the concept of complexity implies, above all, a system, so far as the internal dynamics of a complex structure is concerned, and certainly among other concepts such as multidimensionality, historicity and relationality. Because the term leads us to take into account the many parts or components, and this necessarily in a relational context; otherwise there would be no whole, no complex structure to be considered. The concept of relationality, too, signifies, at least, a certain number of parts, and usually a high number of them. And particularly in the light of our discussion in the last section, we might say that complexity is rather a property of systems, and relationality, in the form of correspondence or parallelism, could be seen as a characteristic mainly of levels, though in reality this may be a semantic point of lesser significance.

As must have been clear so far, and to repeat, the overall picture of the ontological levels of organization appears to be closely related to the idea of systems and the two are evidently complementary. And with the addition of the temporal dimension, that is within a dynamic context, they seem to be ontologically exhaustive so far as a scientific conception of the world is concerned (that is to say, apart from the realm of our values and the mystical and similar sheerly speculative creations). This dynamic scientific conception, as we might perhaps call it, and as I have tried to make clear in earlier sections, is evidently not reconcilable with the traditionally static ontology of the world in philosophy with its essences, noumenae, and what not, that is with almost unchanging and unknowable or unattainable cores, and in which there would apparently be little place for processes.

In accordance with such a view, the problem of what exists is an all-or-none affair - anything either does not exist (in a "real" empirical sense), or else it exists in several basic aspects: It is at one and the same time an entity implying properties, relationships, steady states and processes. If we take a relationship as our ontological departure point, then this would in turn signify entities, their properties, steady states, the related processes or at least one related process; likewise with properties and processes. There can thus be no sort of "ontological referent" without all these ontological units - the former appears to be a conceptual or artificial construct and not an independent existence. The ontologically conscious thinker would conceive and treat it as if there were such a "thing" or "given something".

There seems to be nothing surprising in all this just because reality is relational and complex, and not composed of isolated or single, unrelated existences.

Chapter 2.2

THE DISTANCE BETWEEN THE INORGANIC AND THE BIOLOGICAL REALMS: IS IT CONCEPTUALLY TRIVIAL?

Section 2.2.0

Introductory Remarks

My purpose in this chapter is basicly if not predominantly descriptive, leaving an essentially critical and argumentative evaluation of my main thesis to the last chapter of this part. This should not be taken, however, as signifying a neutral stance, so to say, and it would actually be rather difficult I think, as must the case in the treatment of any philosophically important topic, to draw the distinction between the two approaches. On the other hand, someone with a different philosophical view in the matter of the relationship between the inorganic and the biological realms could certainly present a more or less different account in the way of description in this context, just as it would quite expectedly be the case in the critical consideration of the problem of biological reduction in general.

I shall try, within the possible limits of a doctoral thesis, to make use of the material and the views presented in the last chapter and to incorporate the notion of levels and render them relevant, as much as I can, in my discussions in this chapter. I do hope that what will appear in the end will not be an artificial product, so to speak, but a coherent picture which will help clarify the empirico-logical status of living organisms or entities in my quest for a contribution to the issue of reduction at what we might call the philosophical level. In this way, the allocation of a whole chapter to the idea of levels will not have been in vain.

And for our purposes in this chapter, the terms "inorganic" and "physical" (in its general sense mentioned in Chapter 1.4) on the one hand, and those of "organic" and "biological" on the other, could be used interchangeably.

Section 2.2.1

The Concept of Life

"Life", in its first and foremost sense and like "mind" for instance, appears to be too complex a term with a rather comprehensive scope and, evidently, extremely rich content. From a philosophical point of view, such a complex general term could certainly signify quite different connotations for thinkers widely varying in their approach to philosophical inquiry in general and to a comprehensive consideration of the biological realm of existence in particular. This is understandably one of the main reasons why the present work has been conceived - the very problem of reduction may justifiably be said, I think, to owe its existence to the diversity of conceptual and methodological approaches, views, stances and so on, which we assume when we are confronted with the concept of the biological and its relation to what is physical.

In the Introduction to their work, Invitation to Biology, two authors depart from the definition of biolgy as "the science of life" and suggest that "life does not exist in the abstract"; put differently, "there is no 'life', only living things". "And these living things come in a bewildering variety of forms, from a microscopic but potentially deadly bacterium to a giant sequoia, the largest of all living organisms. They all, however, share certain properties that, taken together, distinguish them from inanimate (that is, nonliving) objects" (Curtis and Barnes, 1985; p.1). The authors then study what they call "the Signs of Life", that is to say, its properties or characteristics. It is my purpose, also, to discuss the issue, above all, in truly empirical if not strictly observational terms, that is, by means of what we establish through our senses plus construct theoretically (and vice versa) for their explanation in scientific activity. Before that, however, it seems to me almost as a philosophical imperative to stress a very basic point in the above quotation.

As a matter of truism or by definition, no general empirical existence can be said "to exist in the abstract", and this is evidently so in the case of "life" as well. However, to assert that "there is no 'life', (but) only living things" would, or at least could, lead to a confusion and, in addition, to the classical philosophical problem of the relationship between the universals and the particulars. Seen in the light of the evolutionary development particularly, and high in the evolutionary hierarchy, living beings exist "arithmetically", so to say, that is in the form of groups - as individuals forming groups composed of sexual partners plus their overall offspring. In other words, life exists in the form of, or is represented by, what we call species which are obviously empirical sets. So conceived, life in its multiplicity is an ontological fact, and not just an epistemological fiction, so to say, as many scientists and thinkers are apparently inclined to see it. In such a general or comprehensively realistic (but certainly non-Platonic) sense, then, life does exist; that is, there is life in empirically abstract terms.

As for those abstract sets composed of the common properties of individual living beings, these are evidently to be regarded as universals expressed linguistically by adjectives ("red", "large", "prehensile-tailed", "mammalian", "intelligent"...). These are to be considered, moreover, in distinction from those collections of individuals in concrete terms with all their characteristics taken together that distinguish them from the individuals of other, different but similarly formed sets representing collectivity; and for which we use nouns expressing species or larger or less comprehensive groups [rose(s), oak(s), spider(s), crow(s), horse(s), spider monkey(s)...]. (The relationship between the two kinds of sets could apparently be kept out of our universe of discourse in this specific context.)

I would also like to replace the very general and supposedly "objective" and seemingly "neutral" term "thing" in the expression "living things" by the philosophically more technical one, entity, or perhaps even by the predominantly existential term being. And this for obvious reasons on my part because I would prefer to use those terms which have been in scientific use in different domains and which would not imply a reductionary bias that comes to mind at the very outset of a philosophical or logico-semantical analysis, because the very basic or characteristic properties of living systems that distinguish them from the inanimate "objects" would thus not be omitted without valid reasons. As for the matter of the relation or connection between the two sets of characteristics, namely those of the nonliving realm and the additional properties of the biosphere, I wonder if I have to stress the point that the main aim of this essay is an attempt to help clarify this issue.

In the work from which the quotations at the beginning of this section have been taken, the term "sign" is apparently used as an equivalent of "characteristic"; but I think that actually it signifies more than that - obviously, and in my view rightly, it denotes the overall distinguishing features of whatever we may mean by the term "life". We may have had the clarification needed on this point following the next three sections on the characteristics of life.

If a definition is a rather coherent and desirably explicit conceptual-linguistic formulation as to what the first and foremost characteristics of the entity, property, relation, process or the steady state under consideration are, then what we are expected to do is to mention, as systematically as we can do, its main and distinguishing properties, and to give a more or less satisfying picture of what it is. As our knowledge, views, approaches and other conceptual tools are logico-semantically operational in a network, however, it seems to me that a definition can never be "ideal", that is, it can neither be definitely exhaustive (or inclusive) nor perfectly exclusive. A definition of the "atom", however comprehensive and exact it may be, would not comprise its role or interactions in a molecular setting.

Seen in such a complex or relational empirical perspective, the concept of Life would signify the common characteristics of living beings, and not just an abstract "entity" with an allegedly doubtful scientific footing. Put quite briefly, life in this sense becomes a collection of characteristics that would distinguish the phenomenon in question, expectedly, from non-life. And however "descriptive" if not necessarily "neutral" I may have claimed to be, my essentially antireductionist approach or tendency would evidently affect my presentation in this chapter, as must have been implied by its title as well.

So far as levels of organization are concerned, it could just be reminded that by definition the biochemical or biomolecular, cellular, organ, system, biological, psychological and social levels have come into being through the evolutionary development or the grand process of what we call life.

Section 2.2.2

Characteristics of Life (1)

I already mentioned (2.1.7) that as Bertrand Russell has justifiably discussed, we are inclined to think that because a word is fixed and definite it must refer to something changeless and substantial, and we do not take into account the fact that, after the removal, so to say, of the attributes like its shape, weight, and the matter which it is made of, and so on, a thing expressed by the word, say, "table", would no longer exist as such (Wood, 1963; p. 58). Hegel, before him, had also questioned this point (Hook, 1955). In other words, and contrary to what has been thought since Socrates (see Plato, 1961; pp. 33, 187), the removal of (all) the properties of any entity would leave no "object without qualities"; this would mean that there could be no "essence without attributes" (Wood, 1963; p. 58).

Seen from such a perspective, there can be no "essence of living entities", hence no room for "life" to be regarded as such - that is to say, there would be no conceptually unattainable core common to all the instances of the former apart from their common and/or basic (or most centrally situated) characteristics which should be enumerated in a definition of the term. A core definition is certainly possible, but what appears to be relevant for us in this essay is a brief treatment of the basic characteristics of living organisms. In any case, as no detailed treatment of any complex concept let alone a core definition of it would be ideally neat and conceptually exhaustive, clearly separable from the network of our definitions of related concepts (for instance, non-life in this context), I shall not be attempting at a perfect conceptual-definitional consideration of the characteristics of living systems. Whatever properties or attributes I may have left out of the scope of my discussion here, my intention will be, in accordance with what I stressed in the introductory part, an optimum use of Occam's razor.

Individuals of species, as "phenotypes", being the foremost living entities in concrete terms, may be considered as units of life in a direct empirical sense, at least for our purposes here and not taking their genetic structures, the "genotypes", as our departure point. Relevantly for us, their coming into being, their growth and its stages, the vicissitudes of their lifetime, and their ceasing to be part of the biosphere through what we call "death" offer quite different stories than what the nonliving systems or entities present in the course of their existence. For a thorough comparison of the two sorts of entities or two realms in nature (and disregarding for the time bing the so-called artefacts produced by human beings), the most suitable way would obviously be, as I have been stressing, to have a look at the possibly distinguishing characteristics of the living or life systems, or their differentiae, and try to see if they are indeed meaningfully (and/or significantly) different from those in the nonliving world (Örs, 1984).

Structurally, life systems appear to be immensely and incomparably more complex. They are constituted by organic molecules or macromolecules some of which are composed of thousands and thousands of atoms. Compared with a subcellular structure such as a mitochondrium or the nucleolus, for instance, a solar system would seem a rather simple entity, in spite of its grandiosity. And relationally, as opposed to the apparent simplicity of relations within, or between the parts of, such systems, living individuals, except perhaps their very primitive forms such as viruses, have a very wide variety of parts, subparts and even smaller parts, all of which reveal quite complex series of interrelationships within and between themselves for the functioning and maintenance, from the teleological perspective, of the system as a whole (Örs, 1984).

As I discussed in a previous section, not fully though (see section 2.1.12), the parts of a living entity, say a high multicellular organism, basicly reveal three sorts of relationship: functional, semifunctional and nonfunctional. The latter is anatomical or topographical, and depend on the neighbourhood or continuity of the parts or organs of the organism. The second arises from the fact that the parts within the same system work together with an overall outcome in relation to certain other part(s), system(s) or the totality of the organism; there may (the respiratory system) or may not (the separately located endocrine glands) be direct continuity within the parts of a system. As for the first kind of relationship within a life system, it is evidently the most characteristic and really significant one so far as the totality of the individual organisms as biological units are concerned. It is what constitutes the function or functions of a part of an organism, whether it is a cell, an organ, a system (Örs, 1978), or any other structure, that is to say, the proper or specific action of the part in question on one or more parts of the organism (Örs, 1984), and that which would contribute to its maintenance, adaptation and development.

In the nonliving realm, too, and perhaps exclusively in the world of human artefacts, we observe what we may call "functional relationships" between the parts of a system such as an automobile or microscopes of different sorts. This seems to be due to the teleological or purposive property or component underlying the corresponding activities of living systems in general (to be discussed presently). In other words, this kind of relationship may be seen as an extension of this property in the case of human beings - change of place being brought about by vehicles instead of legs (only), the capacity of vision being magnified by the aid of lens systems or their functional homologues (based on other principles) instead of seeing with the naked eyes, the capability to strike and kill being realized by means of long-range missiles instead of punching... Such "artificial" means as products of "cultural" development could be created only to serve biological wholes such as human individuals (as social beings) with a view to meeting their demands by enhancing a specific original or natural function of a part of their organism.

This indirect or roundabot kind of teleology with its "hardware structure" must quite evidently be seen, in my view, as a secondary form of purposeful organization and activity, deriving or originating from the need to meet the increasing demands of certain living, "soft" systems at a certain level of organization, and this could possibly include, in principle, all the tool-making species. The matter certainly needs to be discussed more extensively and critically, as has been done by different writers in different contexts.

Section 2.2.3

Characteristics of Life (2)

A living system, an organism, with all its parts functioning smoothly, that is without disturbance at any given time, and granting that the circumstances are not going to be, in the immediate future, so adverse as to threaten its integrity, would adapt itself to the environment in which it "lives". In higher organisms this is secured by the constancy of what is termed the internal environment, their fluid milieu, physically and chemically. And the range of optimum, that is, the most favourable or best conditions, necessary for the maintenance of life processes, contributes to homeostasis, the tendency to uniformity or stability in the "normal" body states (Örs, 1984).

At a somewhat lower level, the significant mechanism in the maintenance of the dynamic equilibrium of the organism is the negative feedback or circular control. Thanks to this balance-maintaining mechanism, the limits of physicho-chemical and organic values of the organism such as those of body temperature, blood pH level or the extent of muscular movement and so on are kept within the range of a "normal" steady state. This is secured by the return of some of the "output" of the related control systems as "input". The overall result would be optimization, or the maintenance of the optimum in what we call normalcy, a dynamic steady state kept within certain limits of values (as regards the vital functions or characteristics or parameters). Any serious disturbance in one of the mechanisms of a subsystem such as a cell or organ would lead to those steady states called diseases, or may even result in the death of the overall system, the organism, with resultant disintegration and destruction at higher levels, thus leading to a much lower level of existence or organization of matter (Örs, 1984).

Another significant characteristic of a living system is the capacity of irritability, of responding to stimuli, internal as well as external. The muscle contracts under the stimulus of the related parts of the nervous system, and salivary glands respond to the presence (or imagining) of food by salivation. Undue increase or decrease of stimuli may alter the structure of a specific region and disturb its fuction, leading to a disease phenomenon (Örs, 1984).

Any region of the biosphere, and living systems in general, are open to continuous exchange of matter and energy with their surroundings (Wicken, 1979). As self-preserving (and species-maintaining) systems, living organisms possess the capacity of negative entropy (Waddington, 1977; p. 143) or negentropy - that is, they resist the apparently general tendency in the universe to increase entropy. (The word "entropy" can be traced to the Greek roots for "energy" and "change", conveying the idea of changed energy or, more specifically, what comes after useful energy when its capacity for work has been exhausted (Wicken, 1979).) They maintain (as negentropic systems) the ordered low-probability states as opposed to the tendency in the nonliving world to high-probability states of disorder (Reichenbach, 1966; pp. 161-162) as a result of the dissemination of energy, hence destruction. They resist destruction by construction, building up organic material of their own. They do tear down complex molecules into simpler biochemical and chemical structures by means of the process called catabolism, but they also build up large molecules out of smaller ones by dint of anabolism (Örs, 1984).

Not a few nonliving entities may be said to possess some of the above-mentioned and perhaps even other qualities of living systems. Glaciers "move", crystals "repair themselves", nonradioactive atoms, crystals and solar systems "reveal the qualities of negentropic wholes" that resist, apparently in principle, the tendency to destruction. But these are shown by part of the nonliving world only, while certain properties such as homeostasis or negentropy appear to be the sine qua non of life systems (Örs, 1984). Besides, and quite significantly, the former have evidently no specific mechanisms for the maintenance of such qualities, negentropy for instance (Örs, 1984), and the entities in question have the same basic structural quality as they had in the beginning with little if ever any development taking place in this respect. The overall development and change in the nonliving world in the universe is apparently a different matter - the principles of (not strictly determinative) causality, chance and so on "responsible for" this change cannot be said, within the limits of modern scientific thinking, to possess an inner mechanism of negentropy or an equivalent of it. And we might perhaps be justified to call the tendency in question in the nonliving world pseudo negentropy because the level of organization at which such entities are composed of are basicly or in principle the same as or very close to that of their component parts - they have no sex, no reproduction, no senses, no perception, no communication, no family, no social life, and so on.

One might also see the issue in the light of an apparently possible generalization or dictum which need not, however, necessarily be all-covering or exceptionless, and this possibly just because of the intersection between the two realms - a critical and comparative evaluation of the physical world and the biosphere need not and should not be unduely analytic and "atomistic"; a general contextual or rather relational approach would give us the opportunity of considering the entities, parts, regularities and so on in question in their different aspects and plurality, which would mean an exhaustive or almost exhaustive enumeration of distinguishing or most significant or salient features of living systems. And this is obviously in keeping with the practice of defining any term, even one that would represent a sufficiently comprehensive concept such as the life comprising the living systems as a whole - any aspect of them seen as entities, properties, processes and so on can be exhaustively considered by means of the enumeration of all of their characteristics with, as a matter of theoretical principle, no residue left.

Section 2.2.4

Characteristics of Life (3)

In the Light of Family Resemblances

As for an overall or "ultimate" and satisfying comparison between the living and inanimate realms, in our context in this chapter at least, we should treat them, I think, in a way analogous to the consideration of family resemblances between entities and phenomena, rather than taking single characteristics as criteria, so to speak, between the individuals of species and nonliving entities. When all the major distinguishing characteristics of living beings are enumerated, no reductionary objection pointing out or referring to a single property such as movement or self-preservation or (pseudo) negentropy would be justified. It is the overall confrontation, so to say, of the essential properties of life phenomena with those of the nonliving entities and processes which would invalidate any view minimizing the distinguishing characteristics of living entities. Then, it would appear that the validity of the strictly reductionary or one-sided arguments would be too doubtful to be taken into account, from both a sceptical (philosophical) and a probabilistic (scientific) point of view.

In terms of the idea of levels, all such considerations would mean that what we might call an ideal definition of life would comprise all the significant or distinguishing characteristics of living beings at those levels of their organization which would give us the best idea of what they indeed are. However, as the choice of levels in question would in principle be determined by one's basic approach to the problem of reduction, whether one is clearly aware of it or not, we have to wait for a critical discussion in the Chapter four of this part to have an overall clarification of the issue.

Section 2.2.5

Family Differences and the Overall Process of Life

Wittgenstein's concept of family relationships could bring in its wake what we might call family differences, for, evidently, we perceive, understand, learn the world by experiencing and conceiving the differences against a background of similarities. We can perhaps express this in the form a relationship between a common field of similarities and an added dimension of differences arising from the gaps existing in the former so far as the ontological units of existence are concerned.

This is evidently quite in keeping (in empirico-logical terms) with the fact that empirical sets, unlike analytic or empty sets, represent vaguely demarcated, inexact similarity classes with no sharp demarcation lines between them (Taylor, 1979; pp. 46-59), a point to be stressed later on.

And in the case of "life", it is obviously this multidimensional intersection between comparable and contrastable empirical sets that would render impossible the drawing of a clear demarcation line between the set of organic entities, properties, relations, processes and steady states and the set composed of those of the inorganic realm. Our general rationalistic tendency to expect from our universe of discourse two apparently logically irreconcilable halves and, at the same time, to "unify" them by means of an operation we call reduction (in its strict form), almost forces us, it seems, to disregard the complex relationality that exists between the related (or relatable) empirical sets.

Much more could be said, certainly, about the validity and/or limits of a sceptical-rationalistic approach to the empirical world, or rather to an inquiry oriented to some part of it. In our present context, and leaving a critical analysis to the last chapter, we might possibly point out in a preliminary manner that we could see the relationship between the organic and inorganic realms in nature as two intersecting empirical sets; this could help clarify the issue in hand even though it would also bring a setback in the form of an undesirable complexity that would apparently resist an "ordinary" or classical philosophical analysis. But this appears to be, in principle, inevitable, because the whole philosophy (so far as the empirical world is concerned) could be considered in this respect as an attempt to find the conceptual limits as regards the states of affairs in a certain part of the world that constitutes a given (and supposedly corresponding) part of our overall universe of discourse.

The above analysis would also give us a clue, I think, as to how we could further see the issue from an organizational levels perspective, although it may be somewhat difficult, at least at the present stage of the evolution of the concept of reduction, to formulate what I have in mind. What such a perspective could give us might roughly be expressed as an inevitably complex interdependency between phenomena at different levels of organization - to concentrate on one or two related levels at an almost total expense of others would mean the elimination of a significant amount of conceptual material from our universe of discourse, even if, in this context, from a possibly descriptive rather than recognizably explanatory point of view.

The very high degree of differences, hence a very high number of variety, observed in the living realm reflect, among other points I think, a dependency on the interactions between levels, for they appear to be an expression of a much higher probability of entities, properties, and so on. Hence, evidently, the immense diversity appearing among the individuals of species as we go higher up in the biological complexity of possibly more than two million species of plants and animals.

Section 2.2.6

From a Biological Standpoint

From a technically biological point of view, the "signs" of life or the fundamental or universal characteristics of living entities, considered somewhat in detail above, could be summarized as follows: the high degree of organization arrived at through the coming together of a vast number of macromolecules; homeostasis, which means the maintenance of a stable and characteristic internal environment, and this in spite of the fact that living systems constantly exchange (energy and) materials with the external environment; the capacity to take in, transform and use energy from the environment, as shown by the process of photosynthesis in the green plants used to power their life processes and to build their characteristic structures, with animals eating plants and changing this into other forms of energy such as heat, motion, electricity and chemical energy; the fundamental and almost universal capacity of responding to stimuli (although different organisms respond to widely varying ones: bacteria move toward or away from certain chemical substances, green plants bend toward light, cats pounce on small moving objects...); the capacity of reproducing themselves with remarkable fidelity, with slight variations in each generation though; the growth and development displayed by most organisms in their stages from the fertilized egg to the mature forms; and an exquisite capacity to adapt themselves to their environment as expressed by their form, size, color, musculature, the capacity of their sense organs, and so on (Curtis and Barnes, 1985; pp. 1-3).

These characteristics or capacities are intimately interrelated and interdependent (Curtis and Barnes, 1985; p.4); for instance, the organization, transformation and use of energy, response to stimuli, reproduction, growth and development, and adaptation to the environment each necessitates, and is in turn necessitated by, the others. And the immense variety and diversity displayed by about two million or more species (not to mention the differences between the individuals) is evidently related to the great differences in, and a combination of, these essential and other characteristics, delimited, apparently, by the circumstances whereby life has become possible. "At any given moment in its life, an organism is organized, maintains a stable internal environment, transforms energy, responds to stimuli, and is adapted to its external environment; the organism may or may not be reproducing, growing, developing (at this given moment), but it possesses the capacity to do so (Curtis and Barnes, 1985; p. 4).

Section 2.2.7

Living Systems, the Optimum and Time

Certain qualities of living systems, such as homeostasis or negentropy appear to be sine qua non of life, as already expressed above (section 2.2.3). The human tendency to "pinpoint reality" (which we apparently share with other, comparable species), conceptually as well as sensorially, to render it more or less readily recognizable, knowable, understandable and which would make action possible, becomes a hindrance, I think, in the way to an overall philosophical evaluation of living systems. Here, the time dimension (or temporality), just as the multifactoriality concerning living systems, seems to be of utmost significance, particularly in developmental terms. In the nonliving world, on the other hand, the past appears, in principle, to be little if ever so important. Such is the case, also, for the future - living systems do consider the coming states of affairs, for they are teleological systems (as we have already touched upon earlier in the chapter and as we shall see presently again in section 2.2.9), while in the nonliving world we observe a complete inertia in this respect. (Understandably, the general dynamic property of all nature and, epistemologically speaking, its predictability, to whatever extent and depending on the kind of phenomena, are beyond the scope of this work.)

As species-maintainig units, life systems come into being, develop and die, "leaving room" for the coming generations. Thus, time or temporality appears to be a particular, evolutionary significance in the realm of life. From the viewpoint of organizational levels and critically speaking, the points mentioned in this section could best be treated, perhaps, in the next section whereby they would preferably be discussed within an overall dynamic context, that is to say with an explanatory force.

Section 2.2.8

Living Beings as Semi-Open Systems

In general terms and generally speaking, and as it is mentioned in the related literature, two basically different kinds of systems are distinguished: closed and open systems. As the term implies, the former are closed off from their environments in the sense that there exists no exchange of material and energy between the system and its environment. In other words, these systems can be described and understood without taking their environment into consideration. On the other hand, open systems depend, in their functioning, on the exchange of energy or matter, or both, with their environment (Gutman, 1964; pp. 10-11) (italics mine).

According to this distinction, and as must be clear I think, all living organisms are to be regarded as open systems. But an open system plus its environment is a closed system. As demanded by the second law of thermodynamics, a closed system attains a state of equilibrium in which entropy has reached a maximum and free energy a minimum. An open system, too, may attain a state of equilibrium, but while as a whole it may remain constant, its component elements may be in flux. This sort of equilibrium has been called "steady state." Once in equilibrium, a closed system does not need energy for its preservation, and no energy can be obtained from it. Thus, to perform work, a closed system must be in a state tending toward equilibrium - not in a state of equilibrium (Gutman, 1964; p. 11).

We must keep in mind that the concepts of "open" and "closed" systems are mere approximations or abstractions. In the actual world, there are no truly closed systems bacause nothing in the universe exists in pure isolation but is subject to the influence of external forces, gravitational or other. Yet, the term "closed system" is still meaningful if it connotes a system that does not depend on its environment for its preservation or functioning, at least not during the time under consideration. The last qualification becomes essential because all systems, with the possible exception of the systems called atoms, have a history in which forces in the environment had something to do with the systems and with what went into them. The neglect of the history of organized structures as well as the disregard of larger systems of which a given system is inescapably a part, spatially and temporally, is responsible for much conceptual confusion pertainig to the functions of systems. Historically speaking, the state of equilibrium of a certain closed system is always due to its becoming involved, at one time, in the functions of a larger system (Gutman, 1964; pp. 11-12).

As mentioned and stressed earlier in the chapter, an exclusive characteristic of a living system is the capacity of irritability, or responding to stimuli, internal as well as external. The muscle contracts under the stimulus of the related parts of the nervous system, and salivary glands respond to the presence of food by salivation. This seems to be closely related to the fact that living systems are susceptible to a continuous excange of matter and energy with their surroundings - accordingly, and as was explained above, they are said to be open systems. On the other hand, however, organisms as self-replicating wholes possess the capacity of negative entropy or negentropy-that is, they resist the tendency in the world to increase entropy, hence destruction. Besides, they are selective in what they intake from without. Thus, living entities deserve to be named, in my view, semi- or partially open systems, for evidently they respond to stimuli and receive energy and matter from their environment in a selective way. This happens, of course, within certain limits of success, and in the event of either too little or too much input, what follows would be disease, disability, or death.

Selectivity appears to be present at every level of the organization of living entities - in the mucosae, that is the inner membranes of those systems that have opennings to and thus contact with the world (respiratory system, digestive system, and so on). The double-layered or double-walled membranes of the cytoplasm and the nucleus, those of the endoplasmic reticulum and the Golgi apparatus and mitochondria within the cell are actually trilaminar membranes with a basicly fluid nature known to secure a passage or transport of matter into and out of the structural unit they surround. This passage may be, biochemically speaking, active or passive depending on the case, that is on the organ and the "matter" in question.

In a way, it seems, living entities are protected from an "inorganically natural or uncontrolled" flow of the states of affairs within the system, that is to say the organism, by a principle of partial openness and the maintenance of a negentropic order.

Section 2.2.9

Living Entities as Teleological or Teleonomic Systems

The question whether the distinction between the living and the non-living is primarily morphological (that is, for our purposes here at least, structural), or functional (Grene, 1974a) appears to me to be a trivial point. Our account so far, particularly that of the previous section, must have shown this. While the organization of matter cannot be thought of without a context of structure or structuring, a functional consideration in turn, becomes meaningless, empirically and/or analytical-epistemologically, in the absence of a relational network of organization. In living beings, as we have seen, the most meaningful if not a very significant aspect of this is brought about by a network of specific relations, namely function or functions, oriented, directly or indirectly, to the maintenance of the overall system. The structural and relational aspects, inseparably interrelated as they are, have an evidently direct relation to the maintenance, development, adaptation and reproduction of the individual; hence of the species. And this seems to be secured by a mechanism, if it can be called so, working, ultimately, for the existence of the overall system represented by the individual living entity or being, and the society (or community) the individual lives in. The essential point here appears to be the apparent "consideration" of the time factor or temporality on the part of the living organism. As our actions are as a rule oriented to our future expectations (cf. Broad, 1962), there seems to be nothing surprising in all these. We might probably establish an analogy with prediction, in a philosophically informal and partial manner though, stressing the "expectation" involved - it is not the scientific spatio-temporal location of events or phenomena with precision, but the probability of a space-time encounter of certain significant expectations for the individual and/or the group, such as food, mate, shelter and so on, that matters in this context. And in man, additionally, the mental aspect of these expectations takes the form of a plan concerning a future action, activity, or realization.

All the above account could justifiably be seen, I think, as one vista that would lead to the concept of teleology which, in our context, would mean the fact or quality of being directed toward a definite consequence or happenning so far as living beings are concerned. The latter are systems evolved in such a way that they act beforehand to obtain or secure a certain state of affairs that is expected to occur later and which we would call an end. (This must certainly be distinguished categorically from the idea of an overall design or purpose which would transcend the individual, the group or a whole species, and ultimately all the species - a belief necessitated at bottom by a mystical force possibly, and analogous to or not unlike the defense of a scientifically unexplainable "entity" such as vital force (of the doctrine of vitalism), which we left out of our discussion from the very beginning.)

We might perhaps mention in this context the concept of inwardness or centricity pointing to yet anotheer characteristic of living entities, and much more conspicuously in the case of animals (Grene, 1974a). It could perhaps be defined quite succinctly as the organizational or "inner" parallel of their behaviour, to use the term in a comprehensive sense, that is, more than and differently from the outwardly observable actions of organisms. This point would certainly deserve and demand much more than a passing mention, but it seems appropriate in this context to elaborate the concept of teleology whereby that of centricity, too, could be clarified, even if indirectly.

In contrast to the inorganic world which is controlled (for the most part perhaps) by the laws of cause and effect, and in which the past determines the future by way of the present, in the living realm what happens now is so arranged that it serves a future purpose, and the happenings of the present appear to be determined by the future rather than by the past. As Reichenbach makes clear succinctly, such a determination in terms of the future, namely teleology or finality, has been assigned, since the time of Aristotle, to the function of a logical parallel of causality. In the generic and not simply correlational sense of the term, determination goes from the past to the future and not vice versa, and neither common sense nor science would admit a generic determination which contradicts causality. Teleology in such an unscientific sense is analogism and a pseudo explanation; it is a confusion - what determines a purposeful action of a living organism is, in reality, not the future occurence but its anticipation of the future which, in the case of human beings, may be called a plan (Reichenbach, 1966; pp. 192-195).

At what we might call the philosophical level, and as Reichenbach goes on quite aptly, it was the great discovery of Charles Darwin that the apparent teleology (in the "classical" sense) of living organisms can be explained in a way in which a combination of chance and selection produces order. The systematic order of coexisting species, in Darwinian terms, represents the historical order of their genesis in the course of evolution and through a process of complexification. The theory of natural selection is the tool by which the apparent teleology of evolution is reduced (or rather is explained in terms of) causality (Reichenbach, 1966; pp. 196-201).

However, and as I have just mentioned already, the term "teleology" has assumed today a different meaning not incompatible with a scientific approach to biological thinking. And this has been necessitated by the lacune left, indeed, by a critical analysis of the concept such as Reichenbach's. If living organisms do have intentions, anticipations, or plans for future action, the formulation of which being amenable to scientific consideration, then we must assign a term that would express the common aspects of these qualities or "internal formulations" in living organisms which can be studied in a way not in contradiction with rationality and a scientific approach. "Teleology" is now used to meet such a requirement, and which is devoid of its earlier transcendental semantical component and is in compliance with today's scientific outlook.

All the same, another term, teleonomy, has recently been coined to distinguish the scientific connotation of the old term "teleology" from its historical "metaphysical" component. The purposiveness or purposefulness in the actions of living beings' has thus become a major aspect of modern biology, whether in the theoretical domain or in concrete research - it appears to be scientifically explainable, verifiable and falsifiable. (I shall further discuss the concept of Teleonomy in its relation to reduction in the last chapter of this part (section 2.4.7).)

Section 2.2.10

Causality, Teleonomy and Genetics

It must be rather obvious, I think, that the purposiveness or teleonomy in living entities involves, at least as a matter of principle or in the final analysis, all the levels of organization concerning them, because it is the totality of their organization with interacting processes that apparently determines their future-directedness through adaptive mechanisms.

In what Michael Ruse calls "genuine teleology", we try to understand the world with reference to the future rather than to the past. We try to understand the eyes and the eggs, for instance, with reference to what they do, rather than or at least as well as with reference to what went on before. We find it illuminating to consider the organic world with respect to its future as well as its past (Ruse, 1983; p. 196).

We see that even when one distinguishes in a clearcut manner between the new, scientific and what we might call the traditional, speculative or perhaps even vitalistic teleology, there would remain a problem which appears to be of a developmental or, using a more technical biological term, ontogenetical nature - an entity could, and should, be viewed in terms of its earliear life or stages. Then it seems to be the case that the earlier stages of a living organism could be regarded, in an explanatory perspective, as being among the "determinants" and/or "initial conditions" of a certain stage, or of its "present" stage, in the sense that the former are the latter's foremost or most determinative producers. Evidently, the other determinants would be constituted, the ratio changing according to the phenomena in question, by what we might call the external, environmental conditions. If the cause(s) and factors and conditions, that is, those phenomena or ontological units that constantly contribute to the emergence or production of what we call the effect(s), that is to say, other though spatiotemporally related phenomena as ontological units, then the former group must by definition be extraneous to the latter. Because an effect appears to be a change, a new "status quo" or steady state, a new existential situation in the states of affairs brought about by what lies outside the scope of the related entity, process, and so on. The internal dynamics of a complex or even a relatively simple system such as an atom (particularly perhaps in the case of radioactivity) can be said to be causally related, in a general and loose sense of the term, to the modified stage, for it can be regarded as a determinant, sometimes without the intervention on the part of the factors external to the system.

But such a somewhat non-analytic approach to the internal dynamics of a system or entity would necessitate a re- consideration of the concepts of cause and causal relationship, a task which is to remain outside the scope of our present context. In any case, however, it seems that it would be most pertinent to pay attention to the (conceptual) danger of confusing the history of becoming of an entity with the entity as it has become. Just because C arouse out of B, and B out of A, we are inclined to think that C is nothing but A in a disguised form (Broad, 1962; pp. 12-13). In other words, the origin and/or earlier stages of an entity and/or process should not and cannot be taken as a constant, direct producer, as it were, of its present stage as we happen to find and observe it. "To analyse anything you must examine and reflect upon it; and the most elaborate account of what preceded it in the course of history is no substitute for this" (Broad, 1962; p. 13). We may have chance to discuss this issue later on in the next chapter with reduction in genetics as its central theme.

Following a related consideration of causality, the relationship between the genotype, that is the overall genetic make-up of an organism, and the phenotype, the adult or partly grown-up organism as the case may be, and as we directly observe and know it, can be conveniently discussed here. And this appears to be an occasion, also, for the consideration of the levels of organization in relation to the topics just discussed. Indeed, the matter of causality in the phenomenon or rather the process of growth or development seems to be inseparably related to the idea of levels, as I hope to be able to show presently.

The idea of growth implies, as a rule, an increase in the dimensions of an entity or system, with an addition of "organized matter" to the already existing organization, and a resulting cumulative change. While the (seemingly) concomitant phenomena of growth at the cellular, subcellular and biochemical levels are delimited by the limiting conditions of living organisms (as we shall consider more argumentatively in the next chapter), these phenomena are certainly deterministically related to the upper-level biological phenomena (as we shall see, again, later on) such as development, growth, aging, and so on. The lower-level occurences and the upper-level (and, perhaps, interlevel) feedback mechanisms "controlling" them possibly at almost every step appear to be intrinsically and most interestingly inter-related, I think, in the transformation of what is called the genetic material into an embryo, fetus, the baby and ultimately the adult organism. This transformation, or metamorphosis if you like, of a unicellular entity into a very complex biological existent deserves, to my mind, a philosophical as well as scientific understanding (see section 2.4.5 and other related sections in Chapter 2.4).

Now, and as I just discussed, phenomena or subprocesses that link the very origin, the unicellular stage of life with its later, "mature" phases appear to be causally related, and this in the sense that they show a regularity and dependency in a temporal order; and the production of one phenomenon at a certain stage would empirically necessitate the realization of another one at a different though related level. But it would be more pertinent, to be able to fully know this relationship, to consider in some detail the genetic structure and its functioning in the human species as is known today and to the extent that it would be necessary to know this in our context.

Section 2.2.11

The Human Genetical Structure and Its Functioning (1)

Unlike Mendelian genetics, to be considered in the next section, we cannot really understand molecular genetics unless we approach the problems of heredity by first considering the nature of the cell. From a molecular point of view, most of the cells seem to be made up (mainly) of two kinds of entities - the structural proteins as the building blocks of the cell that go to make up the walls, membranes, and so on; and enzymes, those proteins which acts as catalysts. The latter enable the cell to go about its chemical activities of building up and breaking down in an orderly manner and at much lower temperatures than such activities would require without their presence. Proteins are, as must generally be known, polypeptide chains or combinations of such chains, which in turn are long, string-like molecules made up of literally hundreds of links, each such link being an amino acid. Proteins have so many parts and play so ubiquitous a role in the cell, with so many different kinds of them and each having different tasks, but the types of amino acid building blocks are restricted to twenty. And although it would seem that any difference in protein structure is a function of a difference in amino acid order, we can build up a very detailed molecular theory of genetics (Ruse, 1983; pp. 197-198).

As we know, the templates located in the cell and serving both for the manufacture of the fresh supplies of protein and for reproducing themselves and thus passing on to new cells the information required for protein synthesis are themselves not proteins but nucleic acids. Of the two kinds of nucleic acids, deoxyribonucleic acid or DNA for short, is found in the chromosomes in large organisms, although in some small organisms with no chromosomes it is to be found on its own within the organism's shell. It is a long large molecule, a polymer of deoxyribose sugars joined by phosphate links. To each sugar is attached a nitrogen-containing base as a side chain; this base is one of four kinds with a certain type of combination - either adenine or guanine (purines) or thymine or cytosine (pyrimidines). Combined with sugars and the phosphates, these bases are called nucleotides. The DNA molecule is normally paired with the two molecules twisted around each other to form a helix. Adenine on one molecule pairs with thymine on the other, and guanine pairs with cytosine; it is in the order of these four bases along the DNA molecule, it is believed, that the information required to make new proteins is carried. One of the two tasks that the DNA must do is <u>replication</u>, whereby the information can be passed on to new cells. In order for this to happen the two strands of DNA in a helix start to come apart; later, with the aid of enzymes, complementary nucleotides line up against the nucleotides on the unzipped single strands of DNA. Consequently, the precise order of nucleotides is passed on to a new strand of DNA, but although the new strand is the complement of the old strand it must duplicate itself before one gets a DNA strand identical to the first one. The second task of the DNA molecule is <u>to make proteins</u>, which it performs not directly but via an intermediary, the ribonucleic acid or RNA molecule. Like DNA, RNA is a long strand of nucleotides, in which there is uracil instead of thymine which the DNA molecule possesses. Three types of RNA are known, each with different functions within the cell: messenger RNA (mRNA), ribosome RNA (rRNA), and soluble or transfer RNA (sRNA or tRNA). Together with some proteins, the rRNA molecules go to form the ribosomes which in turn are the sites of protein synthesis within the cell. The mRNA carries with it the information needed for the synthesis of different proteins. And the sRNA, finally, picks up free amino acids within the cell and brings them over to the ribosome, where they can be lined up in an appropriate order against the mRNA (Ruse, 1983; pp. 198-199).

This sketch of DNA replication and protein synthesis omits many important steps, one of them being that proteins consist of twenty amino acids while RNA, like DNA, carries but four different nucleotides. The implication is that <u>there cannot be a one-to-one correspondence between the nucleotides of mRNA and the amino acids</u> of proteins. It is suggested that three nucleotides code for an amino acid, and that since there are 4X4X4 possible different triplets of ordered nucleotides, many of the triplets are degenerate (that is, code for the same amino acid) and that other triplets make no sense at all (because they do not code for any acids) (Ruse, 1983; p. 199). (My italics.)

As must generally be known, and not disregarding the points mentioned as regards temporality in section 2.1.6, we must remind ourselves of the fact that <u>all</u> organized systems, including man-made structures and with the possible exception of atoms, have a history; the only difference between the living and the man-made systems in this context is that in the former the creative process which led to their construction is intrinsic, whereas in the latter it is extrinsic, emerging from man (Gutman, 1964; p. 22, ftnt.). In general, life is regarded as a historical process, or as a process with history. At the molecular genetical level, one might expect to find a meeting of today's fairly non-historical physics and chemistry, and its fairly historical biology where the concepts are half historical and half not. And something like our thinking about DNA occupies this middle ground - to be told that something is DNA is, in a sense, to be told something about its past, namely that another DNA molecule was involved in its making (Ruse, 1983; p. 213).

It may be said perhaps that while on the most fundamental level of life, that is the living protoplasm, structure is of a fluid nature and constitutes a manifestation of functional phase (Gutman, 1964), at higher levels where structure and function together with their interrelationship are readily discernible, history appears to come to the fore with full force. In other words, the merging of structure and function on the fine structural level (Popper, 1969) may lead to a difficulty in the determination of an explicit historicity, a clear distinction between the two as we observe it at the higher, particularly macroscopic level, such as the heart and its function; and this would demand from us a consideration of the temporally ordered specific phenomena in their relation to each other, that is, the specific functions of the specific parts.

Section 2.2.12

Genetics at the Higher Biological Level

The Mendelian Genetics

Although I shall discuss the matter in more detail in the following section and even more so from an argumentative aspect in the next chapter, I have to begin this section by a mention of genes, the most important concept of genetics, at least so far and using the latter term, in turn, in its most comprehensive sense comprising also heredity as the passing on the tendency of characteristics from one phenotype to another one, that is from the parent(s) to the offspring. Gene is the most dynamic unit of the field of genetics - it would be no exaggeration, I think, to assert that all the scientific research, technical endeavour and philosophical inquiry in genetics is realized around this concept, as I hope to be able to show in my attempt to make use of this field as the examplary topic for a conceptual-critical discussion on reduction in biology. As Mendel demonstrated (Curtis and Barnes, 1985; p. 146), characteristics (or rather the tendencies or traits inherited in the way to their realization) are carried as discrete units which later came to be known as genes.

These units are carried or situated on the chromosomes, and positioned at particular spots called loci. These spots are occupied either by the same kind of genes forming a pair coming from the mother and the father, or by alleles, or genes with alternative different characteristics of the same trait; in the case of Mendel's experiments, for instance, yellow-seededness and green-seededness as the characteristics for the seed color are determined by alleles occupying corresponding loci on homologous chromosomes (Curtis and Barnes, 1985; pp. 141, 173). Mendel showed, besides, that certain pairs of alleles, such as those for round and wrinkled peas, assort independently of other pairs, such as those for yellow and green peas. However, the alleles of two different genes assort independently only if the genes are on different pairs of homologous chromosomes. If two genes are on the same pair of homologous chromosomes, then segregation of the alleles of one gene will not be independent of the segregation of the alleles of the other gene. That is to say, if the alleles of two different genes are on the same chromosome, they should both be transmitted to the same gamete at meiosis (which is the special cell division occuring in the maturation of the sex cells). Consequently, genes that tend to stay together because they are on the same pair of homologous chromosomes are said to be in the same linkage group (Curtis and Barnes, 1985; p. 172). Some traits are sex-linked, that is, they are carried to the offspring through sex chromosomes.

One of the main points genetically significant for us is the fact that chromosomes come in pairs, as do Mendelian factors, and alleles and homologues (homologous chromosomes) also come together in pairs in the offspring (Curtis and Barnes, 1985; p. l62).

Mendel's choice of the garden pea for his experiments, which must widely be known, was not original; this plant was quite suitable for experimentation, and this for various reasons which need not concern us here. What was original in his work was his success in formulating the fundamental principles of heredity. First, testing a very specific model in a series of logical, carefully and imaginatively planned experiments, he chose for study clear-cut hereditary differences, avoiding characteristics that could rather be "more or less" apparent in the offspring. Second, he studied the offspring of not only the first generation but also of the second and subsequent generations. Thirdly and most importantly, he counted the offspring and then analyzed the results mathematically, and even though his mathematics was simple, the idea that a biological problem could be studied quantitatively was startlingly new. Fourthly and finally, he organized his data in such a way that his results could be evaluated simply and objectively, to be repeated and checked by others thanks to their simple description. He had begun with 32 different types of pea plants which he studied for several years before he began his quantitative experiments (Curtis and Barnes, 1985; p. 146).

As a result of his earlier observations, Mendel selected for study 7 traits, such as seed form, seed color, flower position and so on, that appeared as conspicuously different characteristics in different varieties of plants. During his experimental crosses, he found that in every case in the first generation, or first filial generation, F1, one of the alternate characteristics disappeared completely. For instance, all the plants produced as a result of a cross between true-breeding yellow-seeded plants and true-breeding green-seeded plants were as yellow-seeded as the yellow-seeded parent. Characteristics that appeared in the F1 generation, such as yellow seeds and purple flowers, was called dominant by Mendel. On the other hand, he let the pea plant itself carry out the next stage of the experiment by permitting the f1 plants to self-pollinate, and observed that the characteristics that had disappeared in the first generation appeared in the second, F2 generation. These characteristics, which must have been somehow present, although not apparent, also in the F1 generation, were called by him recessive (Curtis and Barnes, 1985; pp. 146-147).

Mendel also noted that the dominant and recessive characteristics appear in the second generation in ratios of about 3:1. And he saw that the appearance and disappearance of characteristics and their constant proportions in the F2 generation could be explained if hereditary traits are determined by discrete factors, or genes, as mentioned earlier. These factors must have occured in the F1 plants in pairs, with one factor being inherited from each parent. The pairs of factors separated again when the mature F1 plants produced sex cells, resulting in two kinds of gametes with one gene of the pair in each. The hypothesis that every individual carries pairs of genes for each trait and that the members of a pair segregate during the formation of gametes is known as Mendel's first law, or the principle of segregation (Curtis and Barnes, 1985; p. 147).

When the alleles of a gene pair are the same, the organism is said to be homozygous for that particular trait; when they are different, the organism is said to be heterozygous for that trait. If the alleles are the same in the matched pair of fertilized egg, both will be expressed. If the alleles are different, one will be dominant over the other; in this case, the organism will appear as if it had only the dominant allele. The outward appearance of a trait (or the sum total of the traits) is known as the phenotype, while the genetic makeup, or the genotype still has each allele independently and as a discrete unit. The recessive (unexpressed) allele will separate from its dominant (expressed) partner when the gametes are formed again. Only if two recessive alleles come together, one from the female and the other from the male, will the phenotype show the recessive characteristic (Curtis and Barnes, 1985; p. 148).

In a second series of experiments, Mendel studied crosses between pea plants that differed in two characteristics. For example, one parent plant had seeds that were round and yellow, which are dominant, while the other had peas that were wrinkled and green, which are recessive. As one would expect, all the seeds produced by a cross between the true-breeding parental types were round and yellow. When the F1 seeds were planted and the flowers allowed to self-pollinate, most showed the two dominant characteristics, few only the recessive characteristics, and the rest were unlike either parent (all, expectedly, in ratios mentioned above). Thus, totally new combinations of characteristics had appeared. While this experiment did not contradict Mendel's previous results, the round and yellow characteristics on the one hand and the wrinkled and green ones on the other hand, which had originally combined in one plant, behaved as if they were entirely independent of one another (my italics). And from this, Mendel formulated his second law, known as the principle of independent assortment, stating that when the gametes are formed the alleles of one gene segregate independently of the allleles of another gene (Curtis and Barnes, 1985; pp. 148-151).

It must be of great interest to us to know that during the 35 years that Mendel's work remained in obscurity, great improvements were made in microscopy and consequently in the study of the structure of the cell, with the birth of the field of cytology. Thus, chromosomes were discovered and their movements during mitosis were first observed and recorded (Curtis and Barnes, 1985; p. 152).

Section 2.2.13

The Human Genetical Structure and its Functioning (2)

We can now go on with the fine structural aspects of human genetics which we already began to discuss in the last but one section. The classical or Mendelian genetics and the modern, fine-structure genetics will have then been considered in a complementary manner.

We know that there are 20 biologically important amino acids and that the primary structure of each particular kind of protein molecule consists of a specific linear arrangement of these 20 different amino acids. And as we have seen, in a DNA molecule there are four different nucleotides arranged in a specific linear sequence. Accordingly, if each nucleotide "coded" (my quotation marks) one amino acid, only four amino acids could be provided for. On the other hand, if two nucleotides specified one amino acid, there could be a maximum number, using all possible arrangements, of 4 square or 16, but still not quite enough. Following the code analogy, therefore, at least three nucleotides in sequence must specify each amino acid. And this would provide for 4 cube or 64 possible combinations, which are called codons (Curtis and Barnes, 1985; p. 189).

As was established in the 1960's, the RNA in a cell is copied directly from DNA of the cell. A complex enzyme known as RNA polymerase catalyzes the copying reaction, and the process is known as transcription. Just as each DNA strand is a complementary copy of an existing strand, each new RNA molecule is copied from one of the two strands of DNA by the same base-pairing principle, the only difference being that RNA contains uracil instead of thymine and the sugar component is ribose instead of deoxyribose. Three different types of RNA molecules (mentioned earlier) are transcribed from the cell's DNA during the process. Messenger RNA (or mRNA) molecules are the working copies of the genetic DNA, each molecule being a long single strand of 1.000 to 10.000 nucleotides. The "instructions" are carried by the molecule in the form of triplet codons that precisely "dictate" the linear sequence of amino acids in a particular polypeptide chain (Curtis and Barnes, 1985; p. 190) (my quotation marks).

Secondly, transfer RNA (or tRNA) molecules are the adapters by which the "language" of nucleic acids is "translated" into the "language" of proteins. These small molecules having a characteristic cloverleaf shape, one end of the molecule attaches to one particular amino acid; the attachment is catalyzed by an enzyme that "recognizes" the particular tRNA molecule and its specific amino acid. A loop within the molecule exposes a set of three nucleotides that form an anticodon, so called because it attaches to an appropriate codon in the mRNA molecule. There exist more than 20 kinds of tRNA molecules in every cell, that is at least one for each kind of amino acid found in proteins (Curtis and Barnes, 1985; p. 190) (my quotation marks).

Third, there are certain structures in the cell called ribosomes, and which are two-thirds RNA and one-third protein. They contain what is called ribosomal RNA (or rRNA). A ribosome is composed of two subunits, differing in size and each with its characteristic rRNAs and proteins. The smaller subunit has a binding site for messenger RNA, and the larger subunit has two binding sites for transfer RNAs with their attached amino acids. When these two subunits are joined together, all the components needed for the assembly of amino acids into proteins are brought about into necessary relationship with one another (Curtis and Barnes, 1985; p. 191).

As for the final protein synthesis, it is called translation because it is the "transferring of information from one language to another" (my quotation marks). As must be clear, we can well dispense here with a detailed account of this process. But it may be pertinent for our purposes to know that a cell does not need all of its enzymes and other proteins at the same time and in the same amounts. One way whereby a bacterial cell regulates protein production is by the rapid degradation of mRNA, while another way is by utilizing a single mRNA molecule to transcribe a series of genes with the related function, as exemplified by the genes for the seven different enzymes involved in the biosynthesis of the amino acid histidine being all transcribed onto a single mRNA molecule. Such a cluster of **functionally related** (my emphasis) genes is called an operon. Studies by F. Jacob and J. Monod showed that the expression of such operons is tightly controlled. Again, for instance, the enzymes for the synthesis of histidine are only synthesized when there is an insufficient level of histidine available to the cell in the growth medium. As a general consequence, the idea has emerged that the DNA molecule consists not only of genes coding for proteins which are known as structural genes, but also of regulatory genes functioning as switches that turn the structural genes on and off (Curtis and Barnes, 1985; pp. 191, 195).

Thanks to new techniques, it has now become possible to make direct comparisons between mRNA molecules isolated from the cytoplasm and the chromosomal DNA segments from which they had been transcribed. It was discovered in the course of such studies that long nucleotide sequences present in the DNA of the original gene were not present in the mRNA from which protein was translated. Furthermore, these long streches of untranslated DNA appeared not only at the beginning or end of the gene, as might reasonably be expected, but also as intervening sequences, interrupting the sequences that code for proteins. These intervening sequences became known as introns, while the protein-coding sequences were termed exons, signifying their expression. Introns must, of course, be excised very precisely, for otherwise a shift of a single nucleotide could alter the "reading" frame and produce "nonsense" (my quotation marks). More recent investigations have implicated some very small

RNA molecules, called small nuclear RNAs (snRNAs), in this process. One suggestion for the way whereby introns establish themselves in the DNA and how they function is that they promote genetic recombination; just because of the distances involved, crossing over in intron sequences would then be more likely to occur. There are suggestions that each exon codes for a different functional segment of the finished protein; the genes coding for the polypeptide chains of hemoglobin, for example, have three exons. On this hypothesis, the introns serve to bring the DNA sequences for these functional modules together in a single gene (Curtis and Barnes, 1985; pp. 213-214).

Section 2.2.14

Heredity, Genetics and the Overall Concept of Levels

I am not sure if, in the light of a brief consideration of the concepts of heredity and genetics with reference to the idea of levels of organization, I shall be able to give here an additional meaningful and functional summary of this section concerning the distance between the biological and inorganic realms. At least, and if it is going to be enlightening at all, this section must invoke in the mind of the reader a clear and definite idea of genetics and heredity, evidently two very basic and interrelated aspects in a conceptual study of living systems.

Life apparently begins, at the concrete individual level, within the framework of the genetic structure or the genotype, and ends with the downfall and disintegration of the individual being, the phenotype, and the ensuing disappearance or loss of its genetic material. As must be clear from the above account, the former is not only a potential carrier of this material to the offspring in case it unites with its counterpart that would come from an individual of the opposite sex of the same species, but also an ongoing determinant of the most significant biochemical reactions, hence evidently a very significant factor in the overall living of the individual itself during all its lifetime.

Between the initial formation of an individual's genotype and the later organization of its phenotype lies the embryological development (in higher species). The genotype appears, from a genetical point of view, to be the necessary condition for (the existence of) the phenotype. The in utero development of the embryo and then (with the formation of the placenta) of the fetus certainly necessitate what we might call, from the perspective of genetics to repeat, the sufficient conditions in the form of different aspects of the environment - maternal, familial, geographical-physical, social, and so on. (Not disregarding, of course, the cases in which changes in the "normal" structure of the genotype leads to those resultant states of pathology in the phenotype called "genetic diseases".)

In a first, pragmatical approach perhaps, the relationship between the genotype and the phenotype, too, could be seen as one involving causality, and if the necessary conditions should be considered within a somewhat definite framework of causal relationship, the general sufficient conditions just mentioned would be regarded, form a biological viewpoint, as contributory factors. Evidently, however, and again, causality in this context would either have too pragmatic a connotation, in the form of a producer-product relationship, or else would mean too complicated a set of occurences in space-time whereby it would be quite difficult if not impossible to make out the links of a causal chain, empirically as well as temporally. The concept of differentation could apparently help us visualize, successfully I think, the flow of the developmental phenomena in terms of eliminations and, mostly, additions of molecular, cellular, tissue and organ components in the overall process of passage from the genotype into the phenotype. In more general terms, metamorphosis in the sense of radical transformation would be a suitable word to express such a quite comprehensive and complex overall developmental process in space-time. In functionally or dynamically scientific-epistemological terms, genetics (including medical genetics) could be seen as the study of the structural and functional effects of the genetic make-up, together with its variations and deviations, upon the phenotype, the organism as we describe and define it. As for the related occurences at different stages of development and at different levels of organization, these would probably be of scientific rather than philosophical concern. What concerns us here would undoubtedly be the totality of the system and the functional relationship of the state of affairs at the beginning to other ones at later stages. And this could bring us to the general characteristics of living beings such as self-maintenance or homeostasis (already discussed in earlier sections) and enhancement or self-expansion.

These two qualities are dialectically connected with each other. "Manifestations of the principle of self-maintenance are anything in the system that is characterized by quality, has permanency and stability, is expressed in regularity and lawfulness, and serves the preservation of self-identity." Those of the principle of self-expansion, on the other hand, are growth, development, productivity, creativity, progression, and spontaneity (Gutman, 1964; p. 33).

Both self-maintenance and self-expansion appear to have teleological or teleonomic qualities and principles. Stated differently, they are also related to another principle concerning living systems, namely teleonomy. The maintenance and expansion of any organism, most conspicuously perhaps at higher levels of organizational complexity, must be supported by, or will be possible almost only in the case of, what we might call "purposive" activity that would link the whole to its future state(s); otherwise self-maintenance and self-expansion, with all their intermediary stages bringing about the mechanisms to be involved, would be "biologically meaningless" and would apparently represent what we could name "totally blind and/or accidental forces". It is the overall structural and functional integration, it must be stressed, that links the purposiveness of the whole to the maintenance of its organization and its expansion at the same time. An "uncaused" type of would-be togetherness between what appear to be the basic principles of life (similar to those occuring at the subatomic level) will evidently not help us at all in the explanation of biological phenomena and to understand them from a conceptual-semantical point of view. To what extent our difficulty lies with the established, in principle or generally anthropomorphic use of the terms "teleology" or "teleonomy", and what degree of objectivity and conceptual clarity we might have in any presentation of our related views, seem to be a topic that would go, if it is expected to be a full-scale discussion, beyond the limits of this work. However, we shall come back to this topic as it will become necessary in later passages.

Growth and development in living beings, as aspects of a metamorphosis representing a "true" or "real" transformation from the genotype to the phenotype, cannot certainly be considered, I think, from a Zeno-manner approach in which the asker questions the issues in clearly separable bits, whereby, in reality, what we have in hand are processes in continuity. What I intend to stress is the relationality of our basic conceptual problem and its relevant concepts. Quite justifiably so indeed, I should add, for otherwise the world would be too simple to be really interested in and to study, evidently not excluding the problem of reducibility, and whether in general or from the viewpoint of biological sciences.

Chapter Three

REDUCIBILITY IN LIFE SCIENCES

WITH REDUCTION IN GENETICS AS A CASE IN POINT

Section 2.3.0

Introductory Remarks

The suffix -ism has many semantic functions, the one in our context serving as "the name of a system or theory or practice" (i.e. "conservatism") or "class-name or descriptive term for doctrines or principles" (i.e. "altruism"). I think that the concept of reductionism has connotations which are related to both of the senses mentioned and, evidently, related or similar ones contributed to by that suffix - it may be regarded as a system or theory, or as a conception with descriptive function for the related doctrine or set of principles. Accordingly, reduction, would carry the usual semantical content or connotations of the dictionary - a theory, that is a conceptual structure with its axioms and presuppositions, or a set of interrelated principles and, stated briefly, with a view to accounting for more by means of less. In either case, the latter term would signify certain assumptions (evidently concerning the empirical world in our context) formulated and to be considered in the light of the semantical analysis of the terms as treated in the introduction to Part one.

In actual practice, the terms "reduction" and "reductionism" are not infrequently used interchangeably, and one may not always be on one's guard to apply them exclusively in their proper places. Although it might be thought perhaps that because of the great semantical intersections between the two terms this would not necessarily constitute an unnegligible problem, I am rather inclined to prefer the former on most occasions on account of its simplicity and, in my view, apparent clarity.

Reduction in biology, or rather in the philosophy of this dicipline (and disregarding here the philosophy of science in general), has a modern temporal dimension extending back to the beginning of the last century, and apparently coexisting with its opposite, antireductionism, as its (dialectical) counterpart (Goodfield, 1974).

Section 2.3.1

Reduction in Genetics: By Way of Example

I think that the field of genetics would be a good, illuminatory example to show that the term "reduction" has a variety of senses leading to a wide range of analyses. In the words of Hull, who has dicussed the issue extensively and referring to Wimsatt in this context, there is no standard, common meaning of "reduction". As a frequently discussed one, the reduction of Mendelian genetics to molecular biology, for instance, should be a paradigm of interlevel theory reduction. Here, a theory couched in terms of entities at one level of analysis, namely genes, phenotypic traits and so on, is reduced to a theory which deals with entities at a lower level of analysis, that is nucleotides, enzymes and others. Can something termed a theory of Mendelian genetics, Hull asks, be deduced from the principles of molecular biology? At one extreme, he notes, claims about reduction can be interpreted as requiring that the two theories be set out, preferably in axiomatic form, with reduction functions formulated and the derivation actually carried out. And nothing in the literature, according to Hull, approached this ideal (by 1979 to be precise); reduction claims, then, are to be interpreted as being (no more than) "in principle". All the claim that Mendelian genetics is reducible to molecular biology is that some theory of transmission (that is, Mendelian) genetics is formulable and derivable, both conditions being in principle and not necessarily actually, from whatever elements of physics and chemistry (irrespective of whether or not these elements are currently available) (Hull, 1979a).

According to Hull (and others), the first view, that of formulability (in principle), is overly naive - no one should expect actual theories and deductions to be sufficiently amenable to reduction in the philosophical sense of the term. The other alternative, that of derivability (in principle), is certainly vacuous, because unless some limits are placed on how massively a theory can be rationally reconstructed, unless something is demanded of the proponents of reduction, any theory, in Hull's view, can be "reduced" to any theory. In consequence, the logical empiricist analysis of interlevel reduction can only be salvaged at the price of extreme trivialization (Hull, 1979a).

In successional reduction, the change in the transformation from one theory to another through time is so great, as is argued, that one is ultimately replaced by the other. The first step here is to interpret scientific theories as historical entities, whereby they would no longer be atemporal axiomatic systems. Thus, successive stages of a theory become stages of the same theory because they are similar to each other; and one theory is an earlier stage of another if it preceded it and is sufficiently similar to it. Here, temporal precedence is assumed, but actual causal connections become irrelevant, the stages being ordered in terms of temporal similarity relations (Hull, 1979a).

Section 2.3.2

Reduction in Genetics: Further Deliberations

In the case of genetics, again, a biochemical explanation is produced for phenomena explained previously in terms of Mendelian genetics. The relationship being too complex for that, geneticists have not been 'reducing' Mendelian genetics to molecular genetics in the sense of providing translation rules (Hull, 1969).

If reduction can be defined as "the explanation of a theory or a set of experimental laws established in an area of inquiry, by a theory usually though not invariably formulated for some other domain", as formulated by Nagel, and as we have seen before (section 1.3.1), two conditions must be satisfied for the reduction of one science (or theory) to another science (or theory). According to the condition of derivability, all the experimental laws and theories of the secondary science (or the reduced, or rather reducible, laws and theories) must be shown to be logical consequences of the theoretical constructs of the primary science (or the reducing laws and theories). The condition of connectibility, on the other hand, can be satisfied by a redefinition of the terms of the se- condary science using terms of the primary science; as no term can appear in the conclusion of a formal demonstration unless the term appears also in the premises, to make reduction possible it is necessary to establish suitable connections between the terms of the two theories. In the case of genetics, for instance, and to express it somewhat differently than before, to effect the reduction of genetics to physical science such concepts as gene, chromosome, and so on, must be redefined in physicochemical terms such as atom, molecule, electrical charge, hydrogen bond, deoxyribonucleic acid and others. As scientific laws and theories consist of propositions about the world, the reduction of one science to another is rather a matter of deriving a set of propositions from another such set (Ayala, 1968).

It may be relevant to mention here the principal features of what might be called the "classical" view on the role of DNA, or what Watson and Crick and then Barry Commoner have called (unfortunately, in the present writer's view) the "central dogma" of molecular biology. As has so far been well established, DNA, desoxyribonucleic acid, which is for the most part localized in the cell's chromosomes, has a double helical structure of complementary polynucleotide strands. As we have already seen, each nucleotide in a DNA molecule containing one of only four bases -the pyrimidines cytosine and thymine and the purines adenine and guanine in the double helical structure a thymine base is always paired with adenine, and a cytosine base always with guanine. On the classical view, all of the cell's genetic information is encoded in the sequence of base pairs in the nucleotide strands. This information is reproduced during cell division by the splitting of the DNA molecule into two separate polynucleotide strands, each of which serving as a template for the production of a new complementary strand. A similar mechanism is considered to be the key to protein synthesis, this in turn determining most of the structures and biochemical processes in the cell. In protein synthesis, the polynucleotide strand serves as a template for the production of strands of messenger RNA, or ribonucleic acid, which then serve as templates for the assembling of proteins out of amino acids on the ribosomes. The sequence of nucleotides in the DNA determines the nucleotide sequence of the messenger RNA which, in turn, determines the amino acid sequence of the resulting protein. Here, too, the determinate pairing of specific bases is the key to translation of the genetic information encoded in the DNA into, ultimately, specific proteins (Howard, 1979).

This "empirical" picture is seen, not unjustifiably I think, as the triumph of modern molecular biology. I shall later discuss, from a critical point of view, the general, philosophical aspects or implications of this success in our context. For the moment, I have intended to mention it (again) as part of, or rather as an introduction to, the presentation of the reductionist view in genetics.

Section 2.3.3

Reduction in Genetics as Related to an Extreme Reductionist View and its Antireductionist Counterpart

The extreme reductionist view, that the "discovery of the molecular basis of heredity means that all life processes are now or will shortly be explainable on a molecular basis," has its counterpart in the form of the proposition that "no interesting biological phenomena have yet been explained by molecular mechanisms, not even genetic phenomena." Another position is what has been called non-vitalist organicism which may be summed up briefly as being the joint denial of the reductionist claim that "all biological phenomena can (eventually) be explained by laws of chemistry and physics" and of the vitalist one that "there are some biological phenomena which contradict the laws of chemistry or physics." The two authors who accept this term, coming from a somewhat earlier date, have formalized (for which, however, they use, not justifiably I think, the term "axiomatization"; see end of Chapter 1.4) the classical, that is, Bateson-Morgan-Mendelian genetics and also clearly axiomatized what they call the (empirico-logical) structure of the fine-structure genetics. According to the position they would like to defend, the present day genetics is a variety of fine structure genetics such that the purine and pyrimidine nucleotides have been identified with subgene components, the evidence for their linear arrangement having been supplied by chemistry. Thus, not only genes but also their four kinds of subunits are linearly arranged, which allows for the extension of the explanatory power of genetic theory beyond that of the classical one. Further, as they state, the purine-pyrimidine pairing mechanism explains the duplication of genes (Lindenmayer and Simon, 1980).

Interestingly I think, in these authors' view we do not need to introduce terms like "messenger RNA", "protein", "coding", and so on, in order to derive a conceptual basis for fine-structure genetics, because we do not need to know more about DNA, for this purpose, than the facts which they have axiomatized, such as "there are four subgene components: the nucleotides adenine, guanine, thymine and cytosine", "genes are segments of DNA strings with specific markers delineating their beginnings and their end points", or "crossing-over between chromosomes consists of simultaneous breaking and healing of DNA double strings at corresponding points on homologous chromosomes", and so on (eight facts or points altogether). According to their view, a detailed chemical description of the above-mentioned molecules and their relationship to protein synthesis is not necessary for a framework of modern genetics. For this reason, they point out, they do not call their account "molecular genetics", because chemistry only provides empirical support to fine-structure genetics, and not a complete framework of the theory of heredity; genetics still has many terms and statements which cannot be given chemical definition, like gametes, fusion of gametes, development of zygotes, and the various phenotypic characters of the resulting organisms (my italics). In this way, classical genetics has been reduced to fine-structure genetics, but the previous theory has not been falsified and the observations which could be explained by it are still repeatable and its explanations still hold (Lindenmayer and Simon, 1980).

Section 2.3.4

Reductionist, Antireductionist Views and the Life Scientist

As it may emerge during an extreme reductionist approach leading to an incorrect theory of a biochemical process, and as is discussed by G. Edelman, the attention must be shifted from that level per se to the level of cell. Of greatest heuristic value would be a two-tier approach which involves both reductionism, that is molecular level, and compositionism, which is related to the level of cells and organism. In another contribution mentioned in Ayala's Introduction, June Goodfield points to the fact that whether several physiologists of the 19th and 20th centuries were (epistemological) reductionists or antireductionists in philosophical outlook seem to have made little difference in their scientific accomplishments. In their approach to experimental research, and crucially from our viewpoint I think, all have been compositionists and reductionists at the same time (Ayala, 1974; p. xii).

Section 2.3.5

Compositional and Evolutionary Theories in Connection with Reduction and Deduction

In the same volume, again, D. Shapere distinguishes two kinds of theories - compositional and evolutionary. While the first provide explanations "in terms of the constituent parts of the individuals", the latter advance answers "in terms of the time-development of items". It often happens that in the search for a compositional theory in a domain the methods and concepts used in some other field are applied, this search thus leading to the unification of fields and on occasion providing what has been called the reduction of one subject to another (italics mine). If reduction is to be understood, according to Shapere, to require "that the concepts of one area are definable in terms of those of the other (area), and the relationships of the former are deducible form those of the latter, ... (then) reduction would almost never have taken place". The "deductions" involved in the reduction of one branch of science to another being not strict, and involving all sorts of approximations, simplifications and idealisations, what we call reduction (in this context) does not imply "that the field reduced would be eliminated; for not only would its laws and individual events not be strictly deducible from those of the reducing theory; its methods, too, might still have much to offer which is inaccessible to those associated with the reducing theory" (Ayala, 1974; p. xiv).

H. Skolimowski has argued that 'modern biology, and especially evolutionary biology, has proved time and again the insufficiency of the physical model of knowledge'. The hierarchy and complexity of living organisms being equivalent to nonreducibility, when we comprehend their function, we go beyond physics and chemistry (Ayala, 1974; p. xiv). The insistence, on the part of organismic biologists, on the importance of functional analysis of living systems is indeed well founded; because they feel the need of focusing on the biological ends of physiological and behavioral processes to develop the conceptual schemes needed in such major areas of biology as morphology, ethology, the theory of evolution and others (Beckner, 1971) (see section 2.4.3).

Section 2.3.6

Certain Basic Antireductionist Terms

One of the terms mentioned above, "compositionism", could perhaps be used interchangeably with "organicism" or "organismic approach". The only, or almost only, conceivable difference would possibly be that the former appears to imply a more general organization of interrelated existents whereas the two latter apparently denote the presence of "organs" (in the biological sense), hence a living organization. As has been mentioned by Ayala (1974), and as we have seen somewhat at length in the last but one chapter, such terms denoting a complexity of relations between the parts of a whole or entity could best be clarified following an analysis of the levels of organization. The term "holism" does not seem to me a very appropriate candidate as a synonym of "organicism" or "compositionism", apparently because of its possible vitalistic or similarly redundant, and, for our purposes at least, irrelevant, and perhaps even obsolescent connotations. This should not mean that this term is used, in its sense relevant to our context, necessarily by those writers whose views I find criticizable or not justifiable; but I doubt whether it could justifiably be used in a relevant modern context and in an apparently "neutral" sense, not differently from organicism or compositionalism, without denoting earlier or historical "suspect" connotations (see Zucker, 1981 for both).

Another significant concept relevant for us is emergence, which implies the appearance of new organizational levels (and/or new entities, relations, and so on) in the course of evolution. The third part on Implications (in addition to the earlier chapter on levels of organization) would be the best place to consider it in considerable length for our purposes in this work.

Section 2.3.7

The Development of the Chromosome Theory of Heredity

What has come to be known as Mendelian or classical genetics is the first experimentally based scientific formulation in modern times that has served the function of explaining the link between the characteristics of the offspring and those of the "parents" - it is a "hereditary" theory to account for the link between the successive generations. Already before Mendel's formulation and thanks to the improvements of the microscopes in the first half of the last century, biologists studying the cell were trying to locate the hereditary material within the germ cells, and a widely accepted answer by 1900 was that the likely location was the darkly staining bodies within the nuclei of cells, that is, the chromosomes. The link between the explanatory or observational data and patterns of inheritance as characterized by the laws of Mendel in the last century and others at the very beginning of this century was established by means of genes responsible for hereditary characteristics. The early genetics with its techniques of artificial breeding was unable to answer the question of where the genes are located. The chromosome theory of Mendelian heredity was based on the fact that properties of chromosomes and genes showed striking similarities, and the conclusion was that the genes are in or on the chromosomes. In later years the ambiguity as to whether the genes were "in" or "on" the chromosomes was resolved in favor of the former. And the theory has become an interfield theory (my italics) bridging the fields of genetics and cytology (Darden and Maull, 1977).

Section 2.3.8

The Molecular Aspect of Heredity

As an important first step, the chromosome theory of heredity eventually led to the development of an explanation of how the genetic material acts as a carrier of information, and also functioned to predict new items for the domain of each field, that is to say genetics or cytology, on the basis of knowledge of the other. Following the discovery of the DNA component of the chromosome as the carrier of the genetic information, the regulation of gene expression was seen to be of particular importance for the understanding of the development of organisms from the embryo to the adult form; that is to say, differentiation that takes place between the two entities should be explained, as well as the problem of the control of genetic information or gene expression. The latter was accounted for, on the one hand, by the operon theory of the control of protein levels in a cell, and on the other hand by the theory of allosteric regulation of the control of protein activity (Darden and Maull, 1977).

One aspect of the control of protein levels, first called enzyme adaptation and later enzyme induction, became a topic of biochemistry fifty years after its discovery in 1900. The discoverer, F. Dienert, had described a process whereby cells adjust the availability of an enzyme in response to the presence of specific metabolites, substances required for growth. This finding was later thought to suggest that gene expression is reversibly controlled by biochemical changes in the environment. The bacterium Escherichia coli, for example, produces higher levels of the lactose-metabolizing enzymes when the galactosides, lactose precursors, are available. In the absence of galactosides, however, these enzyme levels are radically reduced (Darden and Maull, 1977).

Later studies on this bacterium suggested that changes at a site somewhat distant from the genes for the lactose-metabolizing enzymes could affect the expression of those genes. Further investigation of mutants of this i gene and the critical experiment of A. Pardee, F. Jacob and J. Monod in 1959 implicated an i gene product as the controlling substance for the repression of the lactose-metabolizing enzymes (Gilbert and Müller-Hill, 1966, as referred to by Darden and Maull, 1977). In 1961, Jacob and Monod proposed a theory of the operon, a causal theory of biochemical changes that affect specific, heritable patterns of gene expression whereby two kinds of genes were postulated: structural genes which, like the genes for the lactose-metabolizing enzymes, carry the information that determine the molecular structure of enzymes or the information for some proteins other than enzymes, hormones, for example; and regulatory genes, of which the i gene represents only one type, and which are involved in the control of structural genes. According to this theory, again, the lac (lactose-metabolizing) system of E. Coli is an inducible system, enzyme synthesis being induced by the presence of metabolites. Here, induction and transcription of the lactose-metabolizing genes into a cytoplasmic messenger (mRNA) for protein synthesis depends on the state of another regulatory gene called the operator. The structural genes, with their activity coordinately controlled, like the lactose-metabolizing genes, form a unit of control called the operon. If the operator is not locked by the i gene product, which is called the repressor, transcription of the operon begins at the operator. As the repressor is not always in complex with the operator, the repressor itself is controlled by its interaction with the inducer, for instance the galactosides in the case of the lac system. When the inducer is available, the repressor binds the inducer but cannot bind the operator, and transcription of the operon proceeds. On the other hand, when the inducer is absent, the repressor binds the operator and then transcription is blocked (Darden and Maull, 1977).

Evidently, a key question was the mode of interaction between the repressor, the inducer and the operator. Already at the end of the last century, protein function was thought to be associated with protein structure, and more recently Monod and others proposed a causal theory to relate changes in protein structure to changes in protein activity. In this theory of allosteric regulation, the alteration of protein activity (in the case of the repressor, its affinity for the operator) is due to a reversible change in the conformation of the protein when it binds its regulatory metabolite, the inducer (Darden and Maull, 1977).

Section 2.3.9

DNA as the Genetic Material

The confirmation of the Watson-Crick model of DNA structure and duplication on various experimental grounds in the 1950's and early 1960's supported the thesis that the DNA is the genetic material. The development of a fine structure genetics (italics mine) with the structure and function of DNA at the center of the theory, opened up the possibility of establishing identifications between biology and chemistry. The work of certain researchers on the gene indicated that the presicion or resolving power of genetics' methods could be so increased as to make possible the determination of the internal structure of the gene. Heretofore the gene had been alternatively characterised as the smallest unit of mutation, the smallest unit of recombination and as a unit of function, in the sense that it is functionally responsible for the production of a unit character. S. Benzer's studies on the T4 phage of E. coli indicated that the unit of function, which he called a cistron, was analysable into a number of subunits of mutation, the mutons, and recombination, the recons (italics mine). Benzer considered, in the light of the Watson-Crick model, the possibility of translating his 'biochemical' genetics into chemical terms, at least with respect to the number of base pairs of DNA in the various genetic units (Schaffner, 1976).

The DNA molecule, composed of nucleotides which are in turn brought about by very specific bases, phosphates and desoxyribose sugars joined by phosphate links, may be said to have two things to do. The first is replication during which the two strands of DNA in a helix start to come apart and then, with the aid of enzymes, complementary nucleotides line up against the nucleotides on the unzipped single strands of DNA. The precise order of the nucleotides being passed on to a new DNA strand with the complement of the old one, the new strand must duplicate itself before a DNA strand identical to the first is formed. Secondly, DNA has to make proteins via an intermediary, RNA (which has uracil where DNA has thymine). As we have seen, further, there are three types of RNA with different functions within the cell: messenger (m) RNA, ribosome (r) RNA, and soluble (s) or transfer (t) RNA, all being copied off in much the same way as DNA replicates itself. The rRNA molecules, together with some proteins, go to form the ribosomes, the site of protein synthesis. The mRNA travels from the nucleus to the ribosomes, carrying the information necessary for the synthesis of different proteins. And the sRNA picks up free amino acids, building blocks of proteins, within the cell, bringing them over to the ribosomes, where they can be lined up in appropriate order against the mRNA, and joined and cast off as complete polypeptide chains (Ruse, 1983) (italics mine).

The transfer of coding information from the DNA to RNA and then its translation into amino acid chain or a protein is one-way and non-reciprocal. The specific sequence of nucleotides that would be the codon for a specific amino acid brings about the genetic code, and specific sequences of DNA are now known to be related to specific amino acid sequences, the proteins (Schaffner, 1976).

Section 2.3.10

The "Two" Genetics: Concluding Remarks

Mendelian or classical genetics is also called, as has already been mentioned, transmission genetics, a term implying the passing over of the traits (or rather the capacities, inclinations, potentials to be realized, readiness to (phenotypic) properties...) from the genotype to the phenotype. We shall critically discuss the implications of this point in Chapter four of the present part from the viewpoint of our main topic, reduction in biology.

The central assertion of "modern" or molecular genetics, that DNA is transcribed onto mRNA which is ultimately translated into and expressed in the protein, seems to be a qualitative generalization at the molecular biological level admitting of no exception, and not unlike the proposition, at the compositional biological level, that genes carry hereditary information. And, in contrast, to learn the formulation of the assertion that the laws of classical genetics are not universally true, not even as statistical generalizations (as mentioned in Kimbrough, 1979), would make the relationship between the "two" genetics even more interesting from the standpoint of philosophy, as we shall have the chance to consider argumentatively in the related sections to come.

Chapter 2.4

REDUCTION AS A FORM OF (PARTIAL) EXPLANATION

Section 2.4.0

Introductory Remarks

To begin with, the term "partial" in the title of this last and expectedly argumentative chapter of Part 2 has been put in a parenthesis because **reduction as partial explanation** would appear to be too unguarded an expression to be chosen for a heading to capture the main idea of the present work; that **it would not be considered as a full explanation** should be stressed, in my view, in a deliberate manner. It must thus be emphasized that being partial in this context has a "qualitative" rather than quantitative connotation, risking an apparent "contradiction in terms".

All these and other related points will hopefully be made clear at the end of our overall discussion on reduction in the philosophy of science, with our necessarily special emphasis on reduction in the context of life sciences. In a very significant sense, this might be thought of as one of the vital points constituting what we might possibly call "the gist of the matter".

As would be seen from a glance at the section headings of the chapter, and in accordance with the above remarks and the overall content of the work so far, I have tried to establish a balance between, first, the general aspects of theory reduction, or simply reduction, in the philosophy of science; secondly, reduction in biology; and, thirdly, reduction in genetics as a representative case of the second. My stance against what I would dare call "a rather uncritical reductive attitude" must also reveal itself in the "Contents with sections", as well as my utmost care as regards **the semantical aspect of our analysis**, to be sure due to my basic approach to the problems of philosophy. I hope that this approach will be fully complemented by my discussion in the Implications part to follow.

In what follows now, the idea of the concept of organizational levels in nature, to which I have devoted a full chapter, will be a frequent point of reference, although this frequency need certainly not be evenly distributed throughout the sections, and it might only make itself felt, as it were, in certain passages.

The expected originality of the whole work, its actual realization in the course of the overall discussion apart, have been summarized, I hope, in the introductory remarks here to this centrally important chapter.

Section 2.4.1

From a Semantical Point of View (1)

What Do We Mean by "Reduction" in a Biological Context?

As a brief introductory reminder, I could perhaps mention the main idea or departure point underlying the concept of Theory Reduction in the philosophy of science (sections 1.3.1 - 1.3.3). In this context, the condition of connectibility demands that all the concepts (or terms) of a higher-level theory (to be "reduced") must be systematically connected with those of a lower-level, "reducing" theory; and according to the condition of derivability each law of the former must be deducible from the latter, together with the statements that connect the higher-level concepts with the lower-level ones and a description of the relevant boundary conditions in the former's vocabulary. Secondly, reduction has been viewed as a kind of deduction, with the additional expectations such as unification, systematization, increase in precision and clarity, postulational economy, explanation and correction of the reduced theory. Although the basic presuppositions and motivations of this "classical" view of reduction have later been largely criticized, the deliberations have also followed, and a distinction has been made, for instance, between interlevel or explanatory reductions on the one hand and, on the other, what has been called successional reductions.

In our overall context or by way of our main concern in this work, the material we have to consider as **reducienda** is the main characteristics (using the latter word in a broad sense including processes and so on) of living or life systems that constitute the content or rather perhaps the subject matter of biological theories. I have tried to discuss and enumerate the characteristics of these systems (sections 2.2.1 -2.2.3), and tried to stress their **differentiae** as compared with those of the nonliving or inorganic structures. I have also pointed out that (sections 2.2.4 - 2.2.5) rather than comparing the two realms from the viewpoint of a single characteristic such as "movement", "repair", or "negentropy", we have to take into account their overall differences (in a background of similarities), and the idea of family differences together with Wittgenstein's notion of family resemblances could give us a philosophical clue in this respect. The concept of optimum as one of the differentiating characteristics of living realm should be seriously considered, in addition to the fact that living entities which are generally known as "open systems" are in reality **semi-open systems** (sections 2.2.7 - 2.2.8). And lastly in the context of this reminder, whether a "reductionist" or "antireductionist" in philosophical outlook, in their approach to experimental research, biologists have been both at the same time (section 2.3.4).

One of the essential points to be taken into account in the context of a semantical approach to the problem of reduction in life sciences seems to be the relationship between the whole and its parts, because interlevel reduction (in one of the senses the term possesses) is an attempt to explain the "behavior of a structured whole in terms of the laws governing the parts of the whole" (see section 1.3.9). The notion of **system** appears to be very much relevant in this context, a topic to be elaborated as we proceed. At the end of chapter 1.3 on Theory Reduction, I had given a list of terms in connection with reduction in life sciences, and whereby one could have a general view of the related approaches.

The title of the present chapter could be given a different turn by pointing out that as the term "reduction" essentially implies philosophical economy, the semantical content involved should be understood as being a concern of simplification as to the nature of life, the latter term meaning the sum total of the distinctive properties of living or organic systems (see section 2.2.1). In other words, reduction in the context of life sciences can also be seen as the problem of whether the word "life" is (philosophically) meaningful (De Koninck, 1962). If it carries no meaning (of scientific and/or philosophical significance), the term "non-living" (or "inorganic") will carry no meaning either; and to claim, accordingly, that physics and chemistry will eventually explain life away by demonstrating that the non-living is quite enough to account for the living does not seem to have real semantic support on its side (De Koninck, 1962). Such a claim would strongly imply, in my view, a vicious circle - **a circularity brought about by taking for granted the very operation of reduction.** We are trying to see **to what extent life systems** (their structure, functioning, relationships, and so on) **are scientifically explainable, and this in a manner which is philosophically justifiable.** But we cannot do so by accepting from the very beginning the realizability of a total reduction explaining away the higher-level phenomena or totally accounting for the upper-level terms. To put it differently and in more essential terms, **reductionism and antireductionism** (whatever different philosophers may mean by them) **seem to be on the same philosophical** (or, if you like, **"metaphysical") footing.**

An important point for us at this stage could be the use of the term "ontological reduction". The adjective "ontological" is used in different contexts in connection with our topic, such as "ontological theory" (see section 1.3.1), "ontological economy" or "reduced phenomena" (see section 1.3.2), and "scientific reduction (being) a reduction in the ontology of things and properties" or "the reduction of a theory (being) ontologically reductive" (Enç, 1983), and possibly others. In my view, the fact that the physical (see chapter 1.4), in the sense of having an empirical existence or space-time occupancy in the world and whatever the level of organization it may possess, is brought up by the material entities, and that living entities are made of atoms and molecules, could give us no justification to use the term "ontological reduction", either in a scientific or philosophical sense. This was probably a matter of interest, both in science and in philosophy, up to some time in the last century, but it is evidently no longer an interesting or non-trivial point. And I am inclined to disregard the other uses of the term "ontological" in our context, because in my universe of discourse I have a rather sharp distinction between the concepts of **ontology and epistemology**, although they are almost always interrelated and the latter, to put it very roughly, is about the former, even if indirectly sometimes and not necessarily directly. Briefly speaking, what I understand by "reduction" is always something epistemological, actually an operation at the conceptual level with a view of identifying the relationship between such mental constructs as theories or such generalizations as laws concerning different levels or sublevels of organization in the world.

As for the specific use of the term "ontological reduction" by a certain philosopher, one might possibly give the name of W. V. Quine, whose notion, however, has been regarded as being not useful philosophically because it obscures important issues by conflating cases which are quite diverse (Grandy, 1979). And in general, I do wonder if most philosophers would bother about making the distinction between the ontology of the world, which must by definition be objective, however cautiously we may use this term, and our epistemology, which is a human quest to think on and clarify our cognitive and explanatory endeavour to this world.

At the end of the section, I must return to the question in its title, and point out that hopefully it will have been "fully" clarified if not thoroughly answered when the chapter as a whole is completed. But one thing appears to be appreciably certain. To mention in our time and in the context of theoretical reduction such no longer valid terms as "entelechies" or "vital forces" (Hempel, 1966), apparently by way of criticism of certain antireductionist approaches, seems to be quite an unnecessary effort in an already clarified ground - this is not just redundant, but totally irrelevant in today's philosophy of biology, and evidently gives no strength at all to reductive claims.

Section 2.4.2

Levels of Organization and Reduction in Life Sciences

The notion of levels, as we have seen in Chapter 2.1, cannot possibly be thought of separately from that of organization, the coming together or unification of empirical structures or entities within the context of horizontality (see sections 2.1.1-2.1.2). This horizontality will include, furhermore, all the ontological units of the empirical world - entities, properties, relations, steady states and processes (see section 2.1.8). We also discussed the relationship between the levels of organization in the empirical world, and suggested that this relationship could be called "parallelism" or "correspondence", stating further that for both historical and semantical reasons the latter term is preferable (section 2.1.9). Possibly, the term "concordance" can also be used as an equivalent to correspondence in our context. (Terms such as "agreement", "consonance", "accord", "harmony", and possibly others having more or less similar meanings can be dispensed with here for the obvious reason, I think, that it could lead us astray, so to say, as a result of an almost unnecessarily pure semantical treatment of these terms and without sufficient conceptual-semantical clarification.)

We have also discussed in the related chapter comparatively the concept of levels and the idea of systems, and concluded that far from being mutually exclusive the two are interdependent and complementary, representing a combination of hierarchical integration and the unity of the whole (section 2.1.13). Another reminder in connection with the same chapter would be an overall account of empirical complexity, relationality and levels - science or sciences as well as our experiences in different aspects of our lives clearly show us the dynamic, ever-changing and interdependent quality of the world (see section 2.1.14).

In the last section of Chapter 2 in Part 2 on a comparative treatment of the inorganic and biological realms from a conceptual point of view (section 2.2.14), we have considered the concepts of heredity and genetics and that of levels together, with an ensuing understanding of the metamorphosis in the course of the transformation from the (molecular) genotype to the (overall biological) phenotype - quite an interesting process of systematic change, a unique transformation, not to be met with at all in the non-biological world. And to see the matter from another, in a way opposite, perspective, we cannot afford not to take into account the distinction between a live horse and a dead one (De Koninck, 1962). **Death**, whatever its biomedical definition today, and from a general ontological perspective, **means or is deconstruction and disorganization, the lessening of the levels of organization, and the disappearance of complex systems of the biosphere.**

Vital phenomena are the result of a special kind of organization, endowed with the property of ensuring its own survival. And while restraints (such as the circular paths of wheels) in man-made machines are an expression of the designer's intentions, **the organizational restraints of living systems are largely genetically programmed**, and come into being phylogenetically as a result of evolution and ontogenetically during a phase of development. And when we consider any one level of a hierarchically organized system, we see that **the organization of that level is created** not only by interactions between the units of that level imposed by the immediately superjacent level, but **also by the levels cutting across the horizontal levels that add to the hierarchical integration and unity of the whole**. In biology, an entire organism may be constructed from the information at a molecular level contained in the fertilized egg, and in the mature organism the information in each cell is the source of the day-to-day maintenance of know-how (Mercer, 1981) (bold emphases mine).

In the course of the **reduction of the biological to the physical**, the epistemological operation as well as the scientific endeavour of explanation must take into account the quite complex hierarchical nature of biological organization, or the "distance" (see chapter 2.2) between different organizational levels. Otherwise, the unity of the whole, both as an existence with interdependent parts and an instance of vertical integration with correspondences will have been lost out of sight, evidently a basic methodological impossibility.

Mention could also be made here, possibly, of what is called **structural explanation**. And this would apparently be timely from another viewpoint as well, for we are going to consider a "functional account of epistemology", or what is called **functional explanation**, in the next section, whereby we shall have completed the present context.

When the properties or behavior of a complex entity are explained by alluding to its structure, the latter term referring to a set of constituent entities or processes and the relations between them, the resultant explanation may be called a <u>structural</u> one. Such explanations are (evidently) causal, because the structure invoked to explain can also be called the <u>cause</u> of the feature being explained. As opposed to "direct" or "categorical" causal explanations as, for instance, in the case of simple structures such as a pump or a clockwork, where the constituents and their operations are directly known rather than being inferred, the common structural explanations in science are <u>postulated</u> or hypothetical ones, whereby the function of the explanation is not only to help understand the features but also to discover the intrinsic structure of the entity under investigation. And when the hypothesis is a tested one of some generality, we usually call it a "theory". Since this kind of explanation is a hypothetical one and since it is about structures, it may called "hypothetico-structural" (McMullin, 1978).

Structural explanation is evidently closely related to what is called **structuralist thinking**. By way of example for the latter and certainly relevantly in our context, Stuart Mill made a distinction between <u>causal laws</u> and <u>laws of coexistence</u>. While the former express the unconditional succession of events, the latter is about the uniformity of simultaneous existence of phenomena or properties, and some philosophers in our time use the term **structural laws** for them. So far as science is concerned, it is particularly in biology that structuralist ideas have always existed. And **in structuralism today, we find**, among other common points, **an emphasis on the priority of the whole (totality) in relation to its elements** (Puterman, 1980) (my emphases).

It will evidently be relevant, I think, to mention here the interlevel interfield theories whereby two fields are bridged by establishing, explaining and warranting the connections between descriptive levels (Maull, 1977) but do not primarily establish relations between systemic or "structural" (that is, organizational) levels (Juengst, 1985; vol. 2, p. 316). So far as biological objects (or, rather, entities) are concerned, the hierarchy involved here is traditionally presented as one of increasing structural complexity, the inhabitants of each level of organization being made up of and **making up** other objects at other (**and lower**) levels (Juengst, 1985; vol. 1, p. 110) (my emphasis).

Not unlike "systems theory", or rather perhaps the systemic approach involved in it (Agazzi, 1978), the concept of the levels of organization and the underlying **"organizational approach"** are quite significantly <u>transdisciplinary</u> (my emphasis) or inter-disciplinary, terms which would strongly imply the interfield (and/or interlevel) theories epistemologically (and/or "ontologically"). As in the case of systems (Agazzi, 1978) and from a structural point of view, without the inclusion of the concept of levels inside the realm of science (and in biology in particular for that matter), we would not have been able to 'see' the organizational levels where they are present; although, to be sure, and as we have considered earlier in a similar manner (section 2.1.13), the immediate "presence" (or "here and now'ness") of organizational levels is certainly not so conspicuous as in the case of systems.

In the matter of the relation of biology to other natural sciences, Warren Weaver aptly characterized (in 1948) **classical physics as organized simplicity, statistical mechanics as chaotic complexity and biology as organized complexity** (Waterman, 1968). Leaving aside a strictly critical methodological evaluation of this observation, I think we might justifiably remark that on an ontological level, it does express the distinguishing structural and dynamic characteristic of biological phenomena in general - as biological entities or systems, properties, relations, biological steady states and processes. Not to forget, to be sure, that what we qualify as "biological" could in many cases be physical and/or chemical, such as size or colour, observable behaviour, molecular structure or intermolecular reaction, and so on. It is the main thesis of the present work that what should matter as the most significant and "meaningful" point, above all from a philosophical standpoint, is the totality and/or the higher-level aspects of biological organisms and their correspondence to the related lower-level phenomena. We shall consider, and stress on, this point as we go further in the present chapter.

Section 2.4.3

A Functional Account of Epistemology

And its Application to Life Phenomena

By "functional" in this context, I would basicly mean the place of functions in the explanation of biological phenomena, that is to say a first-order scientific concept, rather than a dynamic, relational approach to the field of epistemology in a somewhat basic philosophical sense. To put it somewhat differently and, I hope, more clearly, it is basicly a quest for the explanation of functions in biological entities and its relation to the problem of reduction. Such a quest is known as functionalism, above all in psychology (Enç, 1983), or rather perhaps in the philosophy of psychology, and what I intend to do in this section is to apply this on to the matter of reduction in biology. This is, then, evidently rather different from what is called "the functional view of reduction", which has been developed in opposition to the deductive, formalistic, logical, in short structuralist account of theory reduction (see section 1.3.14).

But before attempting to do so, I am planning to follow a more or less indirect route and take into account certain general considerations in the matter of biological (to physical) reduction.

We have seen that while the earlier thinkers of the concept of organization and organizational levels in nature were interested predominantly in the structural aspects of living organisms (section 2.1.3), those in our time have also been trying to understand, from a philosophical standpoint, the organizing or operational rules defining the functional relationships between the units and regulating their interactions (section 2.1.4). In the light of the principle of emergence, furthermore, the principles (or regularities) organizing an upper level are novelties not necessarily predictable from the levels below; and although the (sub)units of an organization would still operate in accordance with their own principles, they are at the same time subject to additional overriding constraints that establish or impose the organization at the level above (section 2.1.5).

As the reader might know, one of the "champions" of the "irreducibility thesis" in biology in our time has been Michael Polanyi. In his well-known article, "Life's Irreducible Structure", and expressed in a summary form, he argued that whether man-made or morphological (that is, living), mechanisms are **boundary conditions harnessing the laws of inanimate nature, being themselves irreducible to those laws**. For instance, the pattern of organic bases in DNA which functions as a genetic code is a boundary condition irreducible to physics and chemistry; and further controlling principles of life may be represented as a hierarchy of boundary conditions (Polanyi, 1968). His view has certainly not escaped criticism and in a related article, "Polanyi on Structure and Reduction", Robert Causey indicated that although some of his points, particularly about structures, are worthy of serious consideration, they do not prove his irreducibility thesis. Basing his own thesis, in turn, on such concepts as microreduction (or interlevel reduction; see section 1.3.9), actual existence of structures or structured wholes as opposed to their empirical possibility, and indirect reduction through higher levels, he comes to the following conclusion: Polanyi has only shown that the existence of a particular DNA base sequence, demanding a historical or genetic account, cannot be reductively explained in the same way as its empirical possibility, that is that it can exist. He adds, on the other hand, that it does not appear possible to eliminate boundary conditions completely from scientific explanation. He realizes, further, that an indirect reduction of the DNA base sequence will probably always be impossible in practice, but also that Polanyi does not present any argument to show that such a reduction is impossible in principle (Causey, 1969). Leaving aside for the time being a critical consideration of the "in principle" clause (see section 1.3.8, and later discussions in the present chapter), my own emphasis will be on the point that **functions as special and "meaningful" kinds of relationship within an organized whole could be interpreted as boundary conditions on lower levels** (see section 2.1.12) **(as well as on its own , that is biological, level), because phenomena at lower levels thus assume a definite and different role not found, nor "findable", at their own levels.** The point will be further elaborated in later sections in this chapter. The claim that one of Polanyi's basic assertions, that an organism's structure serves as a boundary condition harnessing the physical-chemical processes by which its organs perform their functions, is invalid (Giere, 1968) may be briefly worth considering. The criticism is based, also, on the invalidity of Polanyi's inference from the above assertion that an organism's structure is extraneous to the laws of physics and chemistry harnessed by the organism, and that the morphology of living things transcends the laws of physics and chemistry. The criticism goes on like this. The most that follows granting the premises, is that the morphology of an organism "transcends" those physical-chemical process es which it harnesses and not that it "transcends" all physical-chemical processes (Giere, 1968). In my view, such a critical interpretation of Polanyi's account transcends his thesis on the relationship between the structure and functions of an organism. **The boundary conditions created by the emergence of a biological level of organization sets limits on the physico-chemical processes within that level and/or system, as the case may be, an assertion which should not and cannot be taken as conferring a "transcendentality" to all inorganic processes in nature. Biologically speaking, or within the context of life sciences, those physico-chemical processes that occur within a biological system must be considered in relation to that system and not outside it.**

It seems obvious to me, in the light of my own account presented so far, that the meaning of the term "**function**" can be cleraly understood, and a thorough understanding of the underlying concept realized, **only through a relational account of it in terms of the levels of organization and in connection with the term (and concept) of "structure"** (see section 2.1.12), and certainly not in an exclusive connection with the lower, inorganic organizational levels. In other words, and **never disregarding the explanatory function of intertheoretic reductive operation, nothing can replace the place (or "function") of a descriptive recognition of phenomena at their own levels of organization, to be sure both structurally and functionally, a point we shall emphasize in more than one context as we proceed.**

We may now return to functionalism, the beginning or the introductory topic of the section, but this time with a view to mentioning it as a complementary point to our present discussion. If one of the very basic aims of the scientist is to establish and explain regularities in the form of phenomena occuring again and again, thus "repeating themselves" in the course of time (Örs, 1983a), then a functional law would state causal dependencies or transition regularities, whether deterministic or statistical, between types of states at least one of which is a functional type (Richardson, 1979). The related phenomena could then be called **a functional regularities.**

Furthermore, there are entities in life sciences which are conceived functionally and as processes rather than as structural parts: for example, "sexual reproductive systems", "heat exchange mechanisms", or "territorial behavior patterns". These **functional entities** are accepted and studied by biologists as distinct from the corresponding structural systems, because they seem to meet the cardinal ontological criterion of modern biology, showing significant causes in and consequences for the process of organic evolution. As for the levels of organization to which they belong, it does not seem to be so clear how the ontological scheme could be helpful in relating this class of entities to the rest of biology (Juengst, 1985; vol. 1, p. 111) (my emphasis).

I think that **the consideration of the concept of function in relation to the idea of levels** could evidently be an interesting topic to work on, with possibly significant implications in the matter of reduction, interlevel, intertheoretic, epistemological, or any other. Besides being philosophically rewarding in itself, it would certainly be directly relevant to our discussion in this context. However, I am inclined to mention it in an overall manner here, without a more or less detailed discussion, and hoping that it will be elaborated much further in later works. It might suffice, then, to draw the reader's attention to the fact that **in the course of the actualization of any function, or functional activity** if you like, **the corresponding change in the structure, however slight, must involve <u>all the levels to which that function can be related</u>.** In other words, **given the interdependency of function and structure, and if function is to be seen as a specific kind of relation within an organized whole** (see section 2.1.12), **every step in, or stage of, this relation must be thought of as a corresponding change in the parts involved.** And theoreticly at least, this must be so conceived in the case of every functional activity in biological systems without exception, so far as both these systems and their related "internal" functions (as opposed to their "external" functional relations in which case these would become "internal" functional activities of more comprehensive systems such as human societies) are concerned. When we consider the role of internal secretions or hormons in the process of growth, for instance, and leaving aside the temporality involved in such a "grand" biological process, the biochemical, cellular, tissue, organ, and overall bodily change in the form of (quantitative) increase and (qualitative) differentiation, all the levels and sublevels of biological organization will have been definitely involved. The process of cellular and organ regeneration and tissue repair might be given as similar examples. **All the functions of all the systems of the organism, and those of their parts such as certain cells or subcellular units or their products such as enzymes, could be regarded as activities with all the related constituents of their own and the (relatable) lower levels taking part.**

The point always to be kept in mind and stressed in the matter of function is that functional ascriptions explicitly state that a particular activity of an organized system contribute to some activity of the system as a whole, and that patterns of functional analysis vary considerably depending on the level of inquiry involved (Manier, 1969). Seen in the light of the ontological levels of organization, the above approach would imply **an interlevel relationship in connection with function as a means to the overall dynamic integration.** This interrelationship is **evidently oriented to a teleological or teleonomic "target" as an end (and/or as a means),** a crucial point to be treated in section 2.4.7.

Lastly in this section, the relationship between function and structure can be elaborated from a differently critical and basicly evolutionary point of view. When one thinks of the relationship of structure to function or vice versa, and asks the question, "Which determines which?", habitually one answers, according to H. Gutman, "Structure determines function" and not the other way round. Finding its expression in language as well, it is always an entity that does something: The dog barks, the horse runs, the bomb explodes, etc. Thus, **the activity or the function is always predicated of a subject** (my emphasis). The author, in his monograph on Structure and Function, aptly draws our attention to the fact that one reason for this seems to be that most activities of natural structures are fast enough to be observable by man, whereas the processes that led to the formation of structures as man found them on earth are too slow to be observed directly. Because of this great difference in the speed of processes leading to the formation of structures and, additionally, the activities emanating from man-made structures, our view of the causal relationship in the context of function and structure has become one-sided. The point that must be taken into account is that **all structures are the result of a process of structuring which constitutes the history of the structure** (Gutman, 1964) (my emphasis).

There being a continuous raising of the level from which new development can proceed, spontaneous activity turns eventually into lawfulness. Fluid organization, for instance, becomes frozen into rigid structure; and yet there is a continuous transition from one phase into another. In general terms, **"actualization" of structure leads to function, and "mechanization" of function leads to structure.** And **the solution of the problem "whole versus parts" is difficult for the same reason which obstructs the solution of the problem "structure versus function" - the disregard of the history of structures** (Gutman, 1964) (my emphases).

I do wonder if the concept of emergence, particularly so far as biological levels and systems are concerned, could be sophisticatedly elaborated and justifiably founded in a more able way than Gutman has done. More can certainly be made use of his account, however, in the passages to come.

Section 2.4.4

Reduction in Genetics - A Critical Evaluation

In this and the following two sections, I shall discuss the problem of reduction in biology with special reference to the relationship between the Mendelian or Transmission Genetics and the Molecular Genetics, a topic which has already been treated rather extensively in the literature. In the beginning of each of these three sections I shall try to summarize, by way of reminder and as briefly as possible, the related passages in the earlier chapters, as I have done so far in this chapter and as I shall be doing later on wherever necessary.

On more than one occasion, I have enumerated and tried to stress the main, essential, or overall characteristics of living or biological systems. One of them is that with remarkable fidelity they reproduce themselves, though with slight variations in each generation (section 2.2.6); this means that every time new individuals come into being by means of a specific reproductive process in the existing individuals of a certain species, the very high degree of organization is re-actualized through a complex process of very close copying, and then, in principle, further development and growth. The relationship between the earlier and later stages of this process being apparently causal in kind (section 2.2.10), and especially in the higher species of animals, above all in man, the immense complexity of organization is "transmitted" to the offspring through a very complex set of subprocesses in the course of the functioning of the genetic structure (see sections 2.2.11-2.2.13).

As for reduction in genetics as a philosophical topic, it must certainly be a conceptual elaboration which would account, from an epistemological point of view, **for the close relationship between the two theories of genetics, following each other in historical succession, and explaining the genetical process as it occurs at different levels of organization**

(see sections 2.3.1 - 2.3.3). We have already seen, from both a descriptively scientific and philosophically critical standpoint, several aspects of this relationship (sections 2.3.6-2.3.10), and what we are going to do now is to further elaborate and clarify the issue in a more dynamic way in compliance with the function of this expectedly argumentative chapter.

As not a few philosophers have argued, even in the case of the field of physics (see, for instance, Ruse, 1983; p. 202), the laws of the reduced theory is deducible from those of the reducing theory not in an exact or complete way, that is to say, not deductively but almost always approximately, and sometimes with serious and unsurmountable conceptual-semantical difficulties. And this would mean that a Nagelian-type reduction is not possible. When we come to the relationship between the two theories in genetics, the most important conceptual issue is of course the linking or connection of the molecular (or rather biomolecular) level of discourse to the Gene, the most central concept of the Mendelian genetics (Ruse, 1983; p. 202-203) (although the term "gene" has been introduced later on and not in Mendel's time, let alone by Mendel himself). Molecular geneticists have now appropriated the term "gene" and do include in their meaning of it a piece of DNA just enough to serve as the cause of a cellular product, that is, a polypeptide chain. This being so, the problem then becomes whether we can get a reduction of a kind described by Nagel if we identify particular molecular genes with particular Mendelian genes (Ruse, 1983; p. 203).

This would need the satisfaction of the condition of derivability and that, in turn, would require one to deduce from molecular premises laws of non-molecular cell biology, and in our context Mendel's laws. Mendel's first law, the principle of segregation (see section 2.2.12), demands **that the units of inheritance be the units of function** (Ruse, 1983; p. 203) (my emphasis), a vitally significant, crucial point as we shall soon stress. This holds true of molecular genes as well, and also in another aspect of the same law demanding that the units of inheritance be particulate and not blend irretrievably in each generation (at least in the sense that there is no irretrievable blending of nucleotides). And further, molecular genes, just as Mendelian genes, also meet the requirement that the units of inheritance be distributed in a particular way from one generation to the next. So, all that is needed for a reduction would be that every Mendelian gene has a molecular equivalent and not necessarily vice versa (Ruse, 1983; pp. 203-204) (see section 1.3.15 for one-one equivalence and many-one correspondence).

However, this apparent reductive success of Mendel's first law to molecular genetics can be shown to be illusory when we come to such topics as **mutation and, particularly, crossing-over,** because in these cases we see that the two genetics come into conflict, this seemingly making a reduction along the lines suggested by Nagel impossible - non-molecular genetics supposes that the unit of function, that is the unit of mutation, and the smallest unit of crossing-over, are all one and the same thing, whereas molecular genetics separates out these units. And in particular it allows that **mutation and crossing-over can involve but a very small part of the molecular gene, no more than one or a few nucleotides, of which there can be hundreds in the molecular gene** (Ruse, 1983; p. 204) (my emphasis).

And **in the case of (the revised version of) Mendel's second law, that of independent assortment, too, the hope of getting derivation from molecular biology** by alternative means seems remote if not entirely missing, because it **allows crossing-over between but not within units of function on the same chromosome** - a molecular equivalent to this law would have to allow crossing-over within units of function on the same chromosome. Thus, one could hardly hope to derive Mendel's second law from its closest molecular equivalent, and this would mean that there cannot be a reductive relationship here in the sense Nagel used the term (Ruse, 1983; pp. 204-205) (my emphases).

The phenomenon of crossing-over has been shown to occur by molecular biologists between many of the base pairs of a DNA molecule. Then, it would seem that the smallest unit of crossing-over, that is the unit within which crossing-over is impossible, is probably a single pair of matched nucleotides (Ruse, 1983; pp. 200-201). Furthermore, and even before the discovery of the structure of the DNA molecule by Watson and Crick, biologists had suspected that **the Mendelian or classical gene concept is inadequate**, and that genes cannot be treated like beads on a string. It was discovered, as far back as 1925, that this concept of the gene fails to account for every facet of the complex phenomenon of heredity. The order of the genes on a chromosome, for instance, was shown to affect their phenotypic result, a phenomenon called the "position affect". In more recent decades, and thanks to the developments in the fine structure genetics, more exact concepts have been developed, among them "cistron," "muton," and "recon", dividing the Mendelian gene into three (Ruse, 1983; pp. 205, 206) (see section 2.3.9).

One of the most significant aspects of our present discussion is, in my view, **whether the Gene must be taken, to put it in a moderate and not all-or-none way, as a basicly structural or predominantly functional concept. If the Mendelian gene is the link between one generation and the next, and is in this sense the <u>unit of inheritance</u>, then it is the unit of function** (Ruse, 1983; pp. 13 and 203) (my emphasis), **and this evidently at the overall biological if not necessarily the molecular or biomolecular level of genetics. Seen dynamically, it is through a very complex process extending from the genotypic structure of the fertilized ovum to the phenotypic entity of the ensuing individual(s) and through several levels of biological organization that the genetical function is actualized. "Function", in this context, cannot exhaustively be visualized, I think, as a specific kind of relation or sum total of such relations between a certain part of an organic system or structured entity and the rest of it in a given period of time. It is a very complex empirical flow extending through (a more or less definite period of) time as a very specific kind of ongoing relation whereby a structuring occurs, whose end result, the emergent individual(s), is quite similar to the structured entities in the beginning, the two parent individuals producing the fertilized ovum.**

Section 2.4.5

Reduction in Genetics - Analogical Analysis of a Metamorphosis

As for a clear understanding or visualization of the comparison between the genotype and the phenotype in terms of similarity relations, I think that what must be stressed would be the great difference of "natural logic" or "organic language" in the two cases. While the logic or language of the phenotypes as mostly macroscopic, perceivable units and as we find them in our natural environment is quite familiar to us, that of the genotype, to be conceived as an organization of genes forming a whole of their own, seems to be of a rather unusual type. While the former would evidently remind us, by way of a representative analogy, of a figurative genre of painting, the latter may justifiably be likened, apparently, to the works of Picasso, or perhaps even to those of the cubists.

And clearly, **the overall genetic process should be seen as a metamorphosis at the biological level, a tremendous change on the part of a small organized (and dependent) compact entity, the fertilized ovum, which is so highly capable of development, thanks to its condensed potentiality, into a much larger and much more complex organization, the (relatively independent) phenotype.**

It might perhaps be relevant to add a further analogical remark to the above, but this time one with a rather descriptive, or at least illuminatory, though certainly not an explanatory function. That the movement of water molecules as a group can be referred to as bulk flow (Curtis and Barnes, 1985; p. 83) may be "antireductively appealing" in the present context for it is indicative, however indirectly, I think, of the fact **that water per se cannot be equated with (a) water molecule, that is as we know the former in our natural environment and construct the latter theoreticly.** Water as an entity in physical geography, oceanography, meteorology, or even of physics let alone of our daily life, is not just a huge sum of water molecules; it is something else, however closely connected it may be with **the water molecule** in terms of a determinative relation and whatever the degree of the deductive derivability of its properties from those of the tiny physicochemical entity (and this certainly in conjunction with physicochemical facts and laws other than those directly related to the molecule in question). Water as such is water, and contrary to the related molecule, it flows, for one thing. When, or what stage of their organization, water molecules "become water" may not be so easy to answer, at least on my part.

This seemingly almost vacuous empirical approach to the world as we perceive it directly and also through our instruments such as the microscope(s), and with theoretical entities and other theoretical ontological units is justifiable just because in the matter of reduction we have to first describe and define this world, as Nagel's account presupposes us to do in a more technical way. This may sound rather "phenomenological", but the latter term seems to me to be quite appropriate so long as we do not confuse its semantical content with that of its etymological relative, phenomenology.

Such a conceptual analysis of the relationship between the macro- and micro-worlds in the case of an evidently simple entity such as water may make us aware of the immense difficulty involved in an unduely reductive account of the relationship between the Mendelian and molecular genetics which represent the related complex phenomena at two different and comparatively distant levels of biological organization.

Section 2.4.6

Reduction in Genetics - A Relational Account

It could be quite interesting to see the very complex process of embryological development as **the concrete link between the determined genotype and the emerging phenotype**, and to further analyze it from the viewpoint of the ontological units and the levels of organization in nature (see section 2.1.8). Furthermore, the remarkable transition from one sort of "empirical language" to another through a perfect and high-speed process of organization with an ever ongoing correspondence between the related levels (see section 2.1.9) would be highly rewarding, both intellectually and so far as scientific explanation and philosophical analysis are concerned. The matter could also be studied form the point of view of such related concepts as simultaneity, identity, coincidence and in the light of the idea of systems (see sections 2.1.11 and 2.1.13) - one of them, the concept of identity, is quite familiar to philosophers and the question of whether the phenotype can be regarded as identical with its corresponding genotype would be of interest to them; but more interestingly in my view could be to envisage **the embryological development as one of a changing, evolving, metamorphising process.** The complexity and relationality of the levels of organization (section 2.1.14) can be further emphasized with reference to the fact that biological entities as semi-open systems have a history (see sections 2.2.8, 2.2.11), and this is perhaps to be seen, biologically, in the link or the long chain of phenomena between the genotype and the phenotype.

Whether such considerations could be directly related to our basic topic of reduction in genetics may perhaps be doubtful, but a comprehensive approach to this matter could yield interesting clues in theory reduction in biology and be complementary to a more or less strictly analytical treatment of theories in the philosophy of science (see section 2.2.14).

In the previous chapter I have discussed in some detail the issue of reduction in genetics comparing the two main theories involved together with their development and relationship in terms of the levels of organization in between (sections 2.3.1-3, 2.3.7- 2.3.10). One vital point to be stressed in this context should be the fact that **far from being a temporally limited one, the link between the genotype and the phenotype is a lifelong affair just because,** as we have seen earlier (see sections 2.3.8-2.3.10), **the protein synthesis as the determinant of structural and functional identity of the organism ("the phenotype") is an ongoing, lifelong process dependent upon the genetically determined structure and function of nucleic acids and enzymes.**

As an example for the basicly complex states of affairs in genetics, it may be interesting to note that dominance and recessiveness are not absolute terms. For instance, a gene could be dominant over a second gene, but recessive to a third. Perhaps more interestingly for us in this context, some genes affect more than one characteristic and are known as "pleiotropic" genes. Some other genes, on the other hand, form sets jointly affecting a single characteristic so that the effects of individual genes are not separately distinguishable; these are known as "polygenes" (Ruse, 1983; p. 13).

Given such complex scientific facts as regards genetical phenomena, the case of reduction in genetics, namely the relation between Mendelian and molecular theories, seems to require philosophical reconsideration and re-evaluation. Thus, one would doubt, as Hull does, too (Hull, 1976), whether the biological theory of Mendelian genetics corrected for the purpose of reducing it to molecular genetics could still and justifiably be called "Mendelian theory". Possibly, this is an inevitable aspect of theory reduction in any domain, even within the realm of one single domain such as physics. Even when the two theories will have to be set out in greater detail and the necessary changes specified with greater precision than they have previously been made in genetics (Hull, 1976), **the sacrifice on the part of the reduced theory would seem to be too great for a thoroughly successful reduction to occur which would be in compliance with the logical empiricist expectations. Whether for conceptual reasons** (as in the case of the relation between the terms of Newton's and Einstein's theories) **or on scientific grounds** (as we see in the two theories of genetics), **or due to some other factors, a more or less vigorous intervention with the reduced theory might as a rule be necessary for the reductive operation.** From an overall philosophical perspective, however, and looking at the issue with basicly pragmatical eyes with possible implications in scientific enterprise, this state of affairs would be no reason why we should not continue with our efforts of reduction between related or relatable theories of science.

Scientists follow a similar path in any case, otherwise their discoveries at different and more and more lower levels of organization in their domain(s) of interest would remain unrelated, and both a historical and conceptual continuity in their work would evidently be out of question. What the philosopher of science does in relation to scientific theories appears to be to take a further and sometimes radical step in his universe of discourse from his or her own point of view - which, as I see it, aims at a critical-analytical and conceptual-semantical clarity. An aim that will have been realized, hopefully and to an appreciable degree, at the end of this work, more particularly when the present chapter comes to an end.

Section 2.4.7

Teleonomy and Reduction

I have discussed earlier such notions as Emergence and Temporality in connection with the idea of levels of organization, more particularly in living nature and from an evolutionary perspective (sections 2.1.5-2.1.6). I have also considered the concept of Life, stressing, as it should certainly be done I think, the characteristics of this Process as we find them in living systems (sections 2.2.1-2.2.6). More directly relevant to our present context is our earlier treatment of living entities as teleonomic systems (section 2.2.9) and of genetics in connection with causality and teleonomy (section 2.2.10). (In accordance with my earlier approach (see sections 2.2.9 and 2.2.10), I shall not consider here in any detail the earlier, Aristotelian or other, conceptions of "teleology", and accept as relevant its modern sense expressed by J. Monod through his coinage of the term "**Teleonomy**" (Monod, 1971; pp. 8-10), and by E. Mayr of its adjectival form (Short, 1983)). The earlier consideration of heredity and genetics in the light of the concept of levels (section 2.2.14) and the mention of the compositional and evolutionary theories in connection with reduction (section 2.3.5) might also be reminded in the present context.

I think that among the characteristics of living systems, apparently the most typically "irreducible" one would be their teleonomic feature. Teleonomy can be seen in terms of causality, as Reichenbach has done so aptly and successfully (see section 2.2.9). **But reduction in what we might call its rather strict received form cannot directly be achieved in the case of teleonomic characteristics of living systems, just because, I think, there exists a qualitatively determined obstacle in its way:** You have first to give an account of teleonomy or goal-directedness, as a specific concept in modern biology, in terms of causality, that is as a general empirical notion or principle; and then apply a reductive operation to epistemologically formulate the relationship between the higher-level theoretical construction (in the form of an emergent quality) and the lower-level theoretical entities. Although attempts to clarify the issue by way of analytical formulations to turn seemingly "redundant" teleology into "scientifically acceptable" causality, above all by Hempel in 1959 and by Nagel in 1961 (Cummins, 1975), are certainly justifiable, laudable and useful; as "analytical accounts", however, they do not reach the heart of the problem, so to say, from an overall relational-conceptual point of view, understandably the approach basicly adhered to in this work.

One of the reasons why this is the case appears to be that statements concerning biological functions (these being very much related to the concept of teleonomy) inevitably include an existential component and are not purely law-like in form, and that the use of functional statements serves logically to confine biology to the theoretical form which is proper to natural history (Manier, 1969). On the accounts of functional analysis and explanation, beginning with Hempel's and Nagel's, there have been two basic assumptions: that the point in functional characterization in science (specifically in biology) is to explain the presence of the (biological) item, namely organ, mechanism, process and so on, which is functionally characterized; and, secondly, "for something to perform its function is to have certain effects on a containing system, which effects contribute to the performance of some activity of, or the maintenance of some condition in, that containing system," the latter understandably being a system with "contained parts" (Cummins, 1975). In an approach opposed to this such as Cummins's, the more or less implicit principles only permit the functional analysis to enter the heuristic function and thus seems to bring an explanatory significance; in the structural-functional models generally, what matters is the global activity or total functioning (of the system) and the dispositions of the elementary determinants (Duchesneau, 1977).

Nonteleological explanations place chief emphasis on certain conditions under which specified processes are initiated and persist, and on factors upon which the continued operation of given systems are contingent; teleological ones, on the other hand, focus attention on the culminations and products of specific processes, and upon the contributions of the parts of a system to its maintenance. All in all, the difference between the two is one of emphasis and of perspective in formulation (Nagel, 1970a).

In the explanation of goal-directed or directively organized phenomena of biological organization in which the means-ends relationship is of significance (Nagel, 1970a), **what one does by means of non-teleological explanations is not translation but replacement; the teleology (teleonomy) itself cannot be translated away** (Ruse, 1983; p. 196). If biology, like psychology (Enç, 1983) (and any other science I think), is a special science restricted to a domain of objects, a reduction of a related property, such as teleonomy, may not be realizable through its direct identification (or rather correspondence) with, for instance, physical properties. Besides, just as it is temperature-of-a-gas that gets reduced and not temperature per se (Enç, B., mentioned in Montgomery, 1989), so one might infer in a strongly analogical or parallel fashion that **it is not teleonomic quality per se that is reduced in the case of biological reduction but teleonomy-of-a-living-entity (plurally or universally, -of-living-entities). And this is evidently quite in compliance with our relational or, if you like, "synthetic" (in reality, "analytico-synthetic") account developed here, because an empirical quality in a nomological expression is conceptually considered not in the abstract or separately from the entity (entities) it is related to, but in connection with it.**

Section 2.4.8

Reduction as Oversimplification

We have seen earlier that theory reduction is possibly confused with what is called the analytic approach to a whole (section 1.3.12), and that to the degree that the reduced theories are deductively preserved by the reducing theory, for instance by molecular genetics in the case of genetics, the relation between them could be defended as reduction (section 1.3.13). A theory reduction, in the case of biology for example, should apparently preserve conceptually the basic elements of the **interrelationship between the parts and the whole, between the different levels of organization involved and from the viewpoint of different ontological units** (see section 2.1.8); **the interlevel relationship, particularly in the determinative direction from the lower to the higher ones, could similarly be called correspondence or parallelism** (see section 2.1.9), **or concordance.** The significant characteristics or differentiae of living systems could be seen in the light of the concept of family differences and inexact similarity classes of the empirical world (see section 2.2.5). A two-tier (or perhaps multilevel) approach would be taken into account in reductionism in biology, that is, both at the molecular and compositional (cell and organ) levels; and this has indeed been so in the case of experimental research in physiology irrespective of the researchers' philosophical outlook - that is whether they are reductionists or antireductionists (see section 2.3.4).

It seems that the suffix "-ism" could be used in two rather different though intersecting senses in our context, possibly depending on the approach of the user to the problem of reduction. Thus, the term "reductionism" would either mean, "neutrally", the conceptual operation of reduction; or, in what we might call "doctrinal" manner, an undue defense of this operation using Occam's razor in a direction that would "cut too much" and take away a significant amount out of our universe of discourse (see chapter 1.1). The latter attitude could possibly be called **conceptual oversimplification** in the case of (epistemological) reduction.

In more concrete terms, the issue could be approached to from two different perspectives stressed in this work. First, from the viewpoint of the levels of organization; in which case a many-levelled (Grene, 1974a), or rather **multilevelled ontology** should evidently and inevitably be taken into account. Secondly, from the point of view of systems theory, whereby the part-whole relationship or rather interrelation must be considered; in this case the term "whole" or "sum" (Nagel, 1970b) must certainly be clearly defined. In any case, however, the fact remains I think that in our explanatory attempt at "epistemologically reducing the higher to the lower empirical levels," and in our related philosophical endeavour of clarificatory trimming of the universe of discourse, we may have an undue recourse to Occam's razor, scientifically and/or philosophically, and without being aware of it. As C. D. Broad put it quite succintly decades ago (Broad, (1925) 1962; p. 12), oversimplifying the facts to be explained has been one of the greatest of all mistakes in philosophy.

Perhaps more interestingly for us in this context would be **the joint or overall consideration or rather application of the systems and levels approach**. Microreduction (or interlevel reduction) (see section 1.3.9), for instance, does not always hold, not even in the most ordinary physics. Although it is usually true that where the parts of something go the whole must go too, it is equally true that the parts must go where the whole goes, as in the case of a gas sample and its molecules - the molecules of the sample are governed by it as it is by them. Let us suppose that our sample's volume is suddenly halved at a constant temperature. In such a case, if the gas is ideal, Boyle's law entails that when its pressure settles down it will be twice what it was. That much of its molecules' behaviour is determined -and thereby explained- macroreductively by a law governing the sample as a whole. So the microreduction does not always hold as a principle of explanation, hence, further, as an ontological thesis (Crane and Mellor, 1990). When we mention certain general biological laws later on in this chapter, the conception of levels implicit in such examples concerning entities of interest for physics will be much more explicit beacuse of the increased distance involved in living entities (as discussed in chapter 2.2).

Here, however, we could make mention of an unjustifiable reductive approach in the case of a very basic concept in genetics (and the theory of evolution). In a modern dictionary of biology, **mutation** is defined as "sudden and relatively permanent chromosomal change" (Abercrombie, Hickman and Johnson, 1961). In a later edition of it, this already terse "definition" of the term has been rendered even more economical or succinct: "sudden change in chromosomal DNA" (Abercrombie, Hickman and Johnson, 1973). (One wonders what happened since then, if a more recent edition has appeared; and what will happen in the future when further scientific discoveries may lead to an even more condensed conceptual-linguistic formulation.) I think that such highly economical conceptual formulations of scientific terms are definitely unjustifiable, and this on epistemological grounds as well as for historical reasons; as, for instance, in the case of the concept of Reflex (see Efron, 1977, and section 1.3.5). **What makes the concept of mutation scientifically significant and philosophically meaningful for us is not its being a subcellular and/or molecular phenomenon per se; but, much more importantly from an overall biological perspective, its relational, hereditary aspect which connects this change with the ensuing change in the phenotype, and, further, its population aspect with its evolutionary consequences.** The phrase "relatively permanent" in the earlier definition implies this I think, to however a small extent it may be. The whole relationality and multilevel quality of the phenomenon of mutation has evidently been mutilated to such a degree that the related term has come to mean an only partially expressed structural change. Of course, the concept has been dealt with much more extensively under the related heading in the dictionary, but the terseness of the very first sentence, which would expectedly convey the basic idea in a nuclear form, appears to be highly striking with its underlying strictly reductive rationale.

As one would possibly expect, in neither edition of this dictionary do we find the definition of "life"; it would apparently be quite a redundant business to do so. Reading a related passage in a modern textbook on biology, of which I have rather made an extensive use with Life as one of the concepts considered, we learn that De Vries defined mutation, in the beginning of the century, in terms of characteristics appearing in the phenotype, whereas in the light of current knowledge a biomolecular though somewhat different definition has again dominated the scene: "A mutation is a change in the sequence or number of nucleotides in the nucleic acid of a cell" (Curtis and Barnes, 1985; p. 195).

In this context of a philosophical consideration of **such a dynamic concept as mutation**, we could critically be reminded of the well-known French saying: **"plus ça change, plus la même"**.

Section 2.4.9

Anti-Reductionism

Is it Necessarily a Conceptually Undefendable Stance?

As the above example shows, and as we shall have more opportunity to consider later on in this chapter, **philosophers and scientists with a basicly reductionist turn of mind or attitude are in principle inclined to take reduction in biology for granted**, the former then trying, expectedly, to "philosophically verify" their position. One could certainly be reminded that this is generally the case in philosophy (and elsewhere) and that we have usually a preliminary conception of the topic we intend to develop in our universe of discourse. However, although this is evidently and even inevitably the case for any approach in the matter of reduction, and in that of the biological to the physical for that matter, this "preliminary" conceptual readiness or inclination, as it were, seems to be too strongly entrenched in the minds of many a reductionist to be aware of.

Certain points we have considered earlier in this work might just be mentioned here as approaches that would possibly be related, even if to a limited extent, to this topic; for instance, the analytic approach as a conceptual operation which is confused with reduction (section 1.3.12), or the need for the clarification of principles to explain biological phenomena and which are not reducible to the principles of physics and chemistry (section 2.1.16). The treatment of identity in connection with simultaneity and coincidence, that is to say in the light of temporality and not in isolation from it (section 2.1.11), and functions as boundary conditions on the structural levels of organization (2.1.12), and in reality the whole topic of empirical levels discussed in chapter 2.1, could be conceptually related to our present discussion. Futher, the importance of the optimum in living beings as semi-open systems (sections 2.2.7-2.2.8) could be among the points to be most relevantly mentioned, apparently, in the present context.

A very simple and possibly generally known example, analogical if you like because it is from the nonempirical realm of mathematics, would help me clarify what I could call **a scientifically and philosophically tolerable antireductionist approach**. When three line segments are brought together to form a triangle, they do possess, **as parts of a whole, new, emergent properties and relations** such as those expressed in the theorems related to the angles, and **which are not found, quite evidently, in their earlier separate, unrelated "existence"**. In the case of **historical empirical existences such as living systems**, emergent properties should certainly be viewed and explained in the light of temporality or a temporal flow. This seems to be the very basis of what the defenders of **organismic or compositionalist approach** in the philosophy of biology try to adhere to.

Although a "typical" reductionist like Causey would consider, in his criticism of Polanyi's irreducibility thesis, the historical or genetic explanation to account for the existence of structures (differently from their empirical possibility), and while it does not appear possible to him to eliminate boundary conditions (stressed by Polanyi) completely from scientific explanation, one wonders how what he calls 'indirect reduction through higher levels' could be completely defended (Causey, 1969) - that is, how phenomena of higher biological levels, for instance, could be explained away or accounted for exhaustively in terms of physical theories and laws. As he argues, Polanyi (or any other "antireductionist") may not be able to present any argument to show that an indirect reduction of the DNA base sequence is impossible in principle, but neither does the position of the typical reductionist appear to promise the possibility of its realization. As is not infrequently "imagined" by philosophers, so many states of affairs may be possible "logically"; that the solar system should have been formed from hydrogen atoms by the action of gravitation alone (Giere, 1968), for instance. But what is actually, really significant for us should be **whether such imaginable states of affairs would be possible empirico-logically, that is to say, within the limits of empirical and scientific possibility and not through philosophical speculation.** Causey's example of empirical possibility from the realm of chemistry (Causey, 1969) should be considered in this light.

The claim that terms used frequently by organismic (or compositionist) biologists and (only) occasionally by others, such as "whole," "unity," "integrity," "part," "form," "principle" and so on, are perfectly good words but not technical expressions (Beckner, 1971) seems to me to be rather unfounded. For one thing, they have been given their scientifically operational definitions by those who take them seriously, and to overlook this requires one to be under the impact of physicalism or oversimplicistic reductionism. Secondly, there is no reason why "general words" in any language should not at the same time be "technical expressions", or rather terms; most of the time, the latter, particularly those of a general nature, have not been created out of nowhere but within the context of the already existing vocabulary. Third, that the identity of the etymological form does not imply semantical similarity is certainly true; but that does not at all mean that general words cannot assume the quality of scientific (or philosophical) terms. **The choice and use of technical terms with a comprehensive scope is evidently theory-, perhaps rather approach-laden, and this is the case for the reductionist as well as for those with an antireductionist turn of mind.**

Although it is true that "advances in biology occur only through the use of abstractive method, which proceeds to study various aspects of organic behaviour in relative isolation to other aspects" (Nagel, 1970b), **it is no less true that it is only in respect to the whole ultimately that these advances assume an utmost and irreducible scientific and philosophical significance.**

Section 2.4.10

Causality, Reduction and Explanation

From among the points elaborated in earlier chapters and which may be of relevance in our present context, a few could possibly be mentioned. Temporality as regards the levels of organization in living systems, for instance, may be such a point of significance, for it implies that there must always be a highly complex temporal order in the relationship between levels of organization, and that this is evidently a reciprocal one with its mechanisms of feedback between different but related levels in these systems (see section 2.1.6). We have also seen that causality and determinism are very much relevant in the case of interlevel relationship, because phenomena at one (simple or complex) level determine, to this or that extent, those at another one, and this determinism appears to be reciprocal (see section 2.1.10), that is to say it is both microdeterministic, going from lower to higher levels, and other way round, directed from higher to lower levels and functioning as boundary conditions on the phenomena in the latter. We have considered biological phenomena concerning genetics in the light of causality (taking into account causes in a strict sense, as well as factors and conditions) (section 2.2.10), and also the molecular genetical phenomena as causally determined (section 2.3.8). Quite interesting would be, I think, the mention of the fact that the transfer of coding information from the DNA to RNA and then into amino acid chain or a protein is one-way and non- reciprocal (section 2.3.9).

Understandably, a somewhat detailed analysis of such concepts as causality, cause, causation, cause-effect relationship, causal connection and the related ones would go too much beyond the scope of this section, and of this work as a whole; also, I wonder if it would at all be desired in our context. I have already touched upon the issue from our present perspective, that is, as regards the relation between reduction and causality, in different places above, and I mentioned the main ones among them in the previous paragraph. I might just remark at this point that **causality as a general principle at work in the empirical world appears to be more complex than the more or less simple and even abstract cause-effect relationship, which would be completed with the additional specification of what is classically called "initial conditions".** However, this seems to be a "formula" construed, rather, for or under the impact of the so-called physical sciences; **in the case of such basic scientific fields such as biology with much more complex systems as their units of study, a considerably more complex way of thinking as to the determination of phenomena appears to be necessary with an overall evaluation of cause(s), factors and conditions possibly to be involved.** I discussed the issue earlier and briefly, mentioning the term "multiple causality" (section 2.1.10).

In contemporary biological research, currently, the goal is to reduce higher-level entities (properties, processes, and so on) to those of biochemistry, which we may call "ontological reductionism", and to explain biological processes in terms of the laws governing the reaction mechanisms of physical organic chemistry, which can be called "nomological reductionism" (I shall no longer discuss the former term); this is basicly a quest for mechanism which is embodied in explanatory reductionism, that is to say the interpretation of phenomena through links to the entities and laws of (seemingly) more fundamental sciences (Robinson, 1986). As teleological systems, biological entities would require teleological explanations, but the latter should certainly not be taken as signifying any purposes or ends-in-view, but only that such entities or systems are directively organized; and the "excess" of meaning of teleological statements ("the function of cholorophyll in plants is to enable plants to perform photo-synthesis") can always be expressed in nonteleological language ("plants perform photosynthesis only if they contain chlorophyll" or "a necessary condition for the occurence of photosynthesis in plants is the presence of chlorophyll"). The difference between teleological and non-teleological explanations is, in brief, one of selective attention, rather than of asserted content (Nagel, 1970a). (I would very much like to stress at this point that **the "excess" of meaning mentioned here is something related to a very basic characteristic of living entities and certainly not a semantical redundancy.)** (See section 2.4.7.)

The word "cause" denotes a relation (Reichenbach, 1966; pp. 207-208) between two phenomena, the cause of one being another phenomenon. And one of the meanings of the verb "<u>explain</u>" being "to give or show the reasons of", **it is indeed the causes, wherever possible (and together with the factors and conditions possibly involved), that are introduced into the operation of explanation with the incorporation of the link between the two phenomena in question (namely the cause(s) and the effect), that is to say the mechanism. This means that the question "how" as well as that of "why" should be answered in a scientific explanation of**

phenomena or regularities (covering all the ontological units of entities, processes, and so on). (For a comparison of "why?" and "how?" questions in scientific explanation and reduction, particularly in the case of biological reduction, see for instance Kincaid, 1988). This kind of explanation, that is **causal explanation**, is evidently the typical one at the level of phenomena studied in life sciences.

Although I did not develop it to any appreciable extent (section 2.1.10), I already discussed, the matter of causes, factors, conditions in the light of necessary and sufficient determinants. As must generally be known, it was Claude Bernard who, for the first time, systematically applied the principle of determinism and developed it theoretically in the study of living systems in the last century. Bernard's determinism is based on certainty but is not rigid and inflexibe (see, for instance, Örs, 1978: "Bernard"). The very close relationship between the idea of determinism and the notion of causality must not be taken as one of strong resemblance, hence being very near to identity; in short, the two empirical principles underlying these two concepts must not be confused. **Determinism is expressed in the proposition that under the same conditions the same causes will produce the same effects; it thus becomes the application of the principle of causality on to the prediction of phenomena** (Bourquin, 1952). (Understandably, the (empirico-)logical relationship and difference between explanation and prediction need not concern us here.)

If deterministic laws in biology are compatible with the supposition that the objects characterized by the laws can be analysed into elements which cannot be characterized in turn by deterministic laws, this would mean that whether reduction is also possible depends upon a more technical definition of the reduction relationship (Ackerman, 1969). I would add that this definition should be clear, precise and unambiguous, a point which I shall try to take into consideration in the next section, with a relevant emphasis on theory reduction, particularly in biology. The existence of theoretical compatibility sufficiently indicates, one may conclude, "that the discovery and development of laws which are deterministic may well be very useful and stand as an important scientific achievement in the absence of any reduction to current physical theories" (Ackermann, 1969).

It can possibly be argued that although the emergence of novelties may be unintelligible, that is inexplicable, on the basis of causation alone (and this for obvious reasons), it is understandable, at least in principle, and as M. Bunge puts it succinctly in his Causality (1959), "with the help of the totality of categories of determination, not excluding causation". (It must be clear that "determinism" in this very context denotes a wider range of empirical relationships than that expressed by the same term in the last but one paragraph.) Bunge adopts in this approach **the distinction** introduced by G. H. Lewes (in his Problems of Life and Mind (1874)) **between resultant and emergent properties** (my bold emphasis). While resultant properties are wholly determined by causation, and are (thus) repetitive and predictable in principle, such as weight for example; emergent properties are novel and unpredictable, although they are not unintelligible because they can be accounted for in terms of the categories of determinartion that supplement causation (in the classical, rather strict sense of the term), such as functional interdependence and structural or holistic determination (Goudge, 1967).

If the operation of explanation in science is not to be taken as a rather strict deductive formulation, as not a few philosophers are inclined to do, then **reduction as explanation** may not necessarily be considered as a form of deduction (see section 1.3.2). And, in that case, **reducibility to** would not mean, not necessarily at least, **derivability from.**

Section 2.4.11

From a Semantical Point of View (2)

What is to be Reduced to What ?

We have seen earlier and somewhat in detail the main features and kinds of reduction in philosophy (Chapters one and two of Part one) and, more relevantly for our "specific" purpose here, theory reduction in the philosophy of science with its different aspects and with two different and not infrequently opposing approaches to it (Part one, Chapter three). As regards the latter topic particularly, one might add one or two points in the very beginning of this section. A point to be continually stressed is the fact that in higher-level theories we are concerned with entities of a very complex nature, such as biological systems, especially those of higher order in the evolutionary hierarchy. Consequently, the higher and thus the more complex a biological system is, the much more is "the distance" between the inorganic and the biological realms (see chapter 2.2). Being essentially analogical in nature, the conceptual consideration of this "distance" would expectedly be interpretative in kind; and, additionally, because philosophical questions in our time (Ayer, 1983) are basicly interpretative. This interpretation is, in my own basic philosophical view, critically conceptual-semantical, as the present section must in principle show. I am inclined to stress this point again and again because in the matter of theory reduction, as in philosophical discourse in general, we have preferences of terms, which sometimes differ greatly; and even more significantly, I think, **we do have conceptual preferences as regards the structurally same word - which renders it differently laden from the semantical point of view.**

As the implied conclusion in this section and my overall conclusion in this chapter as a whole must expectedly reveal, and as I have already touched upon it clearly in my Introduction and Presentation, **what we could call reductionary and antireductionary tendencies in philosophy and science, hence in the philosophy of science, have always been present since the very beginning of these activities; it does seem to me indeed that there is no indication that they will disappear, so to say, from the scene of philosophical discourse (certainly not in a "foreseeable" future).** In a way, the main overall implication of the present and the following sections appear to be an emphasis on this "diagnosis" and "prediction". I do wonder, however, if I need add that far from holding a relativist position in the matter of reduction, and in philosophy as a whole for that matter, I shall defend my balanced approach which must have been rather clear so far.

Apparently, the idea of the levels of empirical organization is also not so recent in philosophy; what is recent possibly lies in its conceptual clarification (see sections 2.1.3-2.1.4).

The name of J. J. C. Smart is not infrequently mentioned in the literature on reduction in biology in connection with his book, Philosophy and Scientific Realism (1963), where he is said to argue strongly that to beleive that biology is a science of the same nature as physics and chemistry is a mistake. His claim is based on the denial of the existence of biological laws in the strictest or even strict sense. In his view, biological statements are merely generalizations and not genuine laws, because they lack the generality needed for a universal law and refer to particular things - the word "mouse", for instance, carries implicit reference to the particular planet, Earth, for obviously it denotes a terrestrial species (Macklin and Macklin, 1969; Ruse, 1970; Simon, 1971, pp. 22-23). Here I have no intention to introduce into my universe of discourse a discussion on Smart's argument, for it does not seem quite relevant in my overall context (section 1.3.10 may be referred to for interfield theories in connection with reduction). But one point in his overall and seemingly critical attitude to biology appears to be worth considering.

As one would expect I think, Smart views the laws in genetics accordingly. He claims that Mendel's Law of Segregation (see section 2.2.12) is contradicted by the phenomenon of crossing-over. While, on the one hand, he confuses this phenomenon with that of linkage, on the other hand what he should be talking about is Mendel's other Law, that of Independent Assortment (section 2.2.12). The latter tells us that the way genes segregate at one locus is independent of the way in which genes segregate at another locus. However, this does not hold without major exceptions because some genes at different loci are transmitted together more often than chance would permit; such genes are said to be "linked". Furthermore, even linked genes do not always get transmitted together and their separation is said to be due to "crossing over" (Ruse, 1970).

What basicly interests me in a philosophical study of biological systems is our quite complex network of propositions as regards the structure and functioning of these entities, which is evidently due to their own very complex nature (and if we are to take our biological activity seriously and realistically, and however we regard it in our philosophical thinking). Bearing this in mind, there seems nothing strange in our finding **opposing or even seemingly conflicting, but certainly not logically "contradicting" generalizations within the network of our knowledge as regards the empirical world.** As I mentioned earlier, somewhat differently though, we understand and try to explain the world by what we should call **our empirical logic**, that is through our perceptual experiences, and conceptual formulations and certainly not by means of an almost analyticly logical inquiry. "Exceptions" may not, and need and by definition should not, be the rule as regards the complex entities of the empirical world; however, we should not expect to find in biology, in science as a whole indeed, a nearly perfect logical consistency between the elements of a propositional network, or of a network of universals (Hesse, 1974; pp. 45-73), concerning the empirical realm, that is the world of phenomena. The most we can expect in this respect could be **an empirico-logical coherence** concerning the interrelated statements about phenomena or regularities, but surely not an almost analytic consistency as regards the empirical content of these statements. As a covering term, apparently, we could perhaps use the expression **intersecting or overlapping generalizations** which would include both consistent and conflicting nomic statements in a given context. Let us recall that unlike analytic or empty sets, empirical sets represent vaguely demarcated, inexact similarity classes with no sharp demarcation lines between them (see Taylor, 1979 and section 2.2.5). Collections of similar ontological units of entities, relations, processes and so on should be thought of as such sets or classes; and there would then be no counterintuitive and/or empirically (or empirico-) logical inconsistency within the network of scientific propositions. One could strongly be reminded of fuzzy logic in this context. We should also remember here that in contrast to the mainly **homogeneous classes and generalizations** of physics, such as electrons or hydrogen atoms (Ackermann, 1969), **biological classes are quite heterogeneous**, in which case the elements are individually different from each other (Elsasser, 1981). And this in spite of the fact that "the research must again rely on methods of abstraction" as in the case of non-biological (that is, physico-chemical) sciences (Lagerspetz, 1969).

One very significant implication of our immediate discussion would be a reconsideration, in genetics for instance, of the one-one, many-one, many-many, and even one-many relationships between higher- and lower-level entities, properties, and so on; or of type-type and token-token reductions (see section 1.3.15). In the very last section of this chapter we might consider this point from the viewpoint of the concept of supervenience.

An interesting example for this type of approach to complex systems and phenomena could be found if we considered **the phenomena of homeostasis and heterostasis in biological entities.** The terms "constancy of the internal environment" (Claude Bernard), "steady state" (preferred by von Bertalanffy), (biological) "equilibrium" and "**homeostasis**" (Cannon, Menninger) may be regarded as more or less equivalent. It is **a process of adaptive stabilization whereby a physicochemical constancy is maintained within the organism, such as**

the automatic regulation of body temperature or of blood pH level; here, regulatory forces act and counteract to bring an unbalanced situation back to a prior state of equilibrium. This would certainly remind us of Le Châtelier's law of chemical equilibrium: In a chemical system, when one of the factors which determine the equilibrium is made to vary, the system reacts in such a way as to oppose the variation of the factor, or partially to annul it (Menninger, 1963; pp.81- 83) (bold emphasis mine).

While the notion underlying the concept of homeostasis can be said to go back to the modern times (Menninger, 1963; p. 81), that of **heterostasis,** in psychological terms (at least), may be said to have its known origin in the eleventh century in the work of Ali ibn Hazm. In our understanding of it today, this principle **expresses the progressive moving away from the status quo, and a search for new and unsettled states, in contrast to the automatic return to the comfortable and relatively tension-free previous state of balance.** Both ("negative") psychological states and, at the biological level, a process such as growth can be said to owe their existence, partly (at least), to this principle (Menninger, 1963; pp. 83-86) (bold emphasis mine).

The two principles of homeostasis and heterostasis evidently function together in a dialectical way, to account for, so to say, the overall process of life - in continuity and through change.

Apparently in a parallel fashion, determinism and indeterminism are obviously incompatible alternatives in the methodology (and overall thinking) of a particular science; it seems that no matter what further changes in the structure of a scientific theory may occur, both deterministic and indeterministic regularities can exist without formal contradiction at the level of living organisms as a consequence of mechanisms which in turn are subject to indeterministic physical constraints (Ackermann, 1969). I think that **while we express the principle of determinism, the limiting phrase "under the same (ontological and/or, in Bernard's version, experimental) conditions" strongly implies, or even "empirico-logically entails", the indeterministic aspect or component of the dialectical pair of "determinism-indeterminism".**

The gist of the matter can possibly be explained in the following manner. **In the matter of reduction what we must always take into account is the subject matter which evidently determines the reductive operation from an empirical point of view.** It may perhaps be compared to the fact that while logic and mathematics are formal in the sense that they fit any subject matter, what kind of formalism may be used depends on the subject matter (Hutten, 1960). The two following **universal** generalizations in life sciences are evidently biological and certainly not physicochemical (although implied by them are correlates of the latter type). **Arndt's or Arndt-Schulz law** states that weak stimuli accelerate vital activities, strong stimuli inhibit them, and maximal stimuli abolish or destroy them; and according to **Müller's Law of Specific Nerve Energies**, each sensory nerve, however stimulated, gives rise to its own specific sensation and to no other (Garrison, 1966; pp. 738, 452).

What is most significantly indicated by such instances is possibly the fact, that **phenomena must be viewed and the related generalizations considered both at their own and lower levels of organization. The latter will yield us explanations in the form of causal or determinative mechanisms**, which is different from the meaning of the dual process (Hill, 1971) under consideration; **and the former will certainly give meaning to the mechanisms which would otherwise, or out of context, be "meaningless", that is to say ununderstandable or unrelatable - the genetical material at the biomolecular level would not make sense without reference to the inherited characteristics, that is properties at the biological level, the essential concern of the Mendelian genetics.** It must be obvious that this **relatibility** is the main reason of being underlying the principle of connectibility in theory reduction as was formulated by Nagel.

And this is why, overall, I intend to call reduction "partial explanation" in a rather qualitative sense - without the upper- or higher-level ontological units to be explained or as explananda, the lower-level phenomena lose their function as explanans. This will certainly be seen, by "typical" reductionists, as too obvious to be worthy of mention, or as a truism. But the matter does not appear to be so simple, as the following **emphasis on (empirico-) semantics** must show.

Phenomena concerning life sciences occur in what we may call **the biological context.** In the study of biochemistry, for instance, the organizing principles that constitute the "molecular logic" of cells should serve as a frame of reference (Lehninger, 1970; p. 14) (my quotation marks). **The phenomena or ontological units of study at every level of organization of spatiotemporal existence must be considered, quite evidently I think, in their empirical fullness or entirity; and this inevitably means, in turn, that it must be reflected in our propositional context, too. In other words, and to put further emphasis on my main point, our conceptual-semantical framework should capture both the "highest" level of organization in question and the lower ones so far as they can be found philosophically (as well as scientifically) relevant, conceptually operational, and (empirico-) semantically "meaningful". In the explanans-explanandum or, more specifically in our case, the reduciens-reduciendum context, the former has a philosophical (as well as scientific) significance only in reference to the latter; otherwise it is, in my mind's eye, devoid of any conceptual-semantical significance (except, of course, at their own level or in their own right).**

The difference in the semantics concerning the lower-higher-level interrelation, or the (conceptual-semantical) "residue" as it is frequently termed, can best be expressed, possibly, by reference to an analogical example which has apparently been in vogue in the philosophy of science. Then, my consideration and semantical analysis of it will expectedly bring a clarity, also, to "the meanings of the biological terms" and to the matter of "extensional definitions" (Hempel, 1966), to that of "coextensionality" with reference to reduction (Enç, 1983) and to the question of "existential component" included in the statements concerning biological functions (Manier, 1969) (and, I think, structures).

As I expect my readers to know quite well what the term "Eddington's table", or rather his "two tables", mean, I shall only mention it insofar as I see it valid in my analysis in a context of reduction, of the biological to the physical as well as in general. While one of these two "tables" is, according to the reputed physicist, the macroscopic object as we know and make use of in our daily lives, the other one is represented by the wonderful, extraordinary, quite unusual world of subatomic particles with almost unbelievably interesting interactions between them. In reality, however, as one and the same physical object, it is both (Cartwright, 1979). **Semantically speaking, there is indeed just one table - and it is the object, a human artifact, with one or more functions, and irrespective of whether it is interesting, beautiful, expensive, and so on, or old, shabby, ugly, valueless or even useless. The wonderful world of the physicist is "nothing more than" a scientifically interesting and significant aspect of it,** subject both to the laws of macrophysics and microphysics (Cartwright, 1979). **Otherwise, it is the macroscopic entity, the table, as we perceive and interprete it, if you like, which is wonderfully interesting as table, as nothing else but table, and not its "ultimate structure". This is the semantical gist of the matter in the treatment of the question of reduction if for no other purpose, philosophical and/or other.**

If we agreed with Eddington as to the existence of two tables, the commonplace one with its extension, colour, and permanence, and the scientific table composed of myriad minute particles in empty space and being "the only one which is really there", this would certainly imply that (expressed in such an aptly way) we should suppose "the existence of sub-atomic particles to require **the non-existence of** atoms, molecules, tables, trees... or animals or people with minds" (Crane and Mellor, 1990) (my bold emphasis). According to the network model (of universals) and in M. Hesse's terms, Theoretical Explanation is understood as redescription and not as causal relationship between distinct theoretical and observational domains of entities mysteriously inhabiting the same space-time region; hence, "Eddington's two tables are one table" (Hesse, 1974; p. 44).

As in the case of "the systematic identification of adult and gametic characteristics" in genetics (Manier, 1969), the uncritical reductionist or identificationist or in-principilist, as you like, will be strongly inclined to overlook the basic semantical aspect in the matter of reduction. And quite possibly also, for instance, the fact that a biochemical geneticist is not only a biochemict but also a geneticist, "because he is involved in the sort of gross biological phenomena studied by Mendel" (Beckner, 1971).

And philosophers of science involved in reduction, and whether they are "reductionists" or "antireductionists", should certainly make clear what they do mean by such terms as "reducibility" and "irreducibility", "organismic biology" or "organicism", and so on.

Chapter 2.4.12

From a Philosophically Functional Point of View

Why to "Reduce" Anything to Something Else ?

Our discussion in earlier chapters and/or certain sections on theory reduction and on different reductive operations in philosophy must have given us clues as to why we make attempts at all to conceptually "reduce" entities, relations, processes and so on to others of their kind or to different sorts of ontological units; and this irrespective of whether we do so from an epistemological, methodological or "ontological" point of view (chapter 1.3, particularly sections 1.3.1-2, 1.3.5-7, 1.3.9, 1.3.13-14, 13.17-18). In chapters 2.2 and 2.3, we have tried to apply the operation of reduction on to the phenomena which make up the subject matter of biology, with special reference to those studied in genetics; and we have made an attempt, wherever possible, to exploit the concept of the levels of empirical organization, studied in some detail in chapter 2.1, to be able to help give a fuller account of the issue of reduction in life sciences.

All this we have tried to achieve, as is the rule in the matter of reduction, and in the treatment of any philosophical issue or topic indeed, at **what we might call the logical, locigo-philosophical, or rational-conscious level.** We should perhaps call this level internally philosophical, whereby philosophy **is evaluated in a functional manner within its own dynamics - with all its essential presuppositions, clear definitions, "logical" inferences, and other basic conceptual tools at the philosopher's disposal being required for his or her universe of discourse.** Philosophers of science interested in reduction, whether in general and/or in the field of biology, must also assume, evidently and inevitably, such a rational, logical, "philosophical" attitude to their activity, as the mention of a few related terms and expressions as a reminder would clearly reveal: "a simple deductive-nomological explanation" (Cummins, 1975); "hypothetico-deductive method"; "hypothetico-structural explanation" (McMullin, 1978); "what is to reduce what?" (Goosens, 1978); the qualifier "in principle" signifying a claim which is not being realized in practice because the model is a kind of idealization (Wimsatt, 1979); "local maxima of regularity and predictability in the phase space of different modes of organization of matter" (Wimsatt, in 1976, as mentioned in Hull, 1981);

"indirect reduction through higher levels" (Causey, 1969); Schaffner's "peripheriality thesis to the effect that reductionism is not a primary aim of molecular biology" which is puzzlingly paradoxical with his assertion that this thesis "is resulting in at least partial reduction of biology to physics and chemistry" (Hull, 1976); "the internal reduction of a branch, where it is reduced to a subbranch," which is one of "four related processes, all of which are called reduction" (Kemeny and Oppenheim, 1970); additionally to be mentioned in this context could be "an irreducibility thesis (justifiable) for methodological reasons", but "any attempt to twist this into a claim of real irreducibility for all time is, in the light of the contemporary work in molecular biology, logically untenable, empirically unwarranted, and heuristically useless" (Schaffner, 1967a). Lastly, and according to one view, "the ultimate test of a science's systematic nature and logical autonomy is axiomatization", and in biology the only portion that has thus far been completely axiomatized is classical genetics, realized by J. H. Woodger using the formal apparatus of Whitehead and Russell's Principia Mathematica (Simon, 1971; p. 26).

Besides, the philosopher's interest in reduction in natural sciences is often motivated, to a large extent, by the hope that a sufficient understanding of inter-theoretic reductions will provide insight into traditionally philosophical problems, such as the (so-called) mind-body problem or the complex issues concerning phenomenalism (Sklar, 1967).

Even the basic presuppositions **and motivations** of what I have called the classical view of reduction, that is, "a well-defined, completable, and in some cases completed task," fitting in well with the paradigms and presuppositions of logical empiricism, have in general been highly criticized by most writers (Wimsatt, 1979) (my bold emphasis). The word "motivation" used in this context is certainly to be clarified. Although this usage has taken place in a more or less technical article in the matter of reduction in philosophy, and supposedly has a mainly logical-professional meaning, "motivation" has a rather well established, central or nuclear psychological sense which strongly implies urges of mainly psychic origin. Reduction as a philosophical matter, too, is a highly emotional issue, as judged by Schaffner when he wrote a critical article on antireductionism in biology (Schaffner, 1967a), with the subtitle, "Though the antireductionist thesis is unwarranted, research in classical biology may well be of value", and when he observed the ensuing reactions on the part of different academic circles (Hull, 1981).

According to Karl Popper, philosophical reductionism (in distinction from that in science), which seems to be closely allied with essentialism, is a mistake, and is due to a wish "to reduce everything to an ultimate explanation in terms of essences and substances, that is, to an explanation which is neither capable of, nor in need of, any further explanation" (Popper, 1974). We see such an urge in the so-called "neutral monism", as defended by Russell (and as he says he follows a suggestion of H. M. Sheffer) - this, he explains, is neither materialism nor mentalism. "It is monism in the sense that it regards the world as composed of only one kind of stuff, namely events; but it is pluralism in the sense that it admits the existence of a great multiplicity of events, each minimal event being a logically self-subsistent entity" (Russell, 1956; p. 293). I think that Russell's "plurality" is rather far from saving the appearances (a favourite term of his), and the underlying essentialism is too conspicuous to conceal - what is that kind of stuff, taken to be events? Emerson's words on this "metaphysical" topic appear to be more "honestly" expressed, that is, without recourse to the technical language and to any concealment on the part of the philosopher as regards his more or less mystical tendency: "Everything in Nature contains all the powers of Nature. Everything is made of one hidden stuff." (MacDougall and Hegner, 1943; p.7, quotation).

In terms of psychology as a very significant domain studying certain external determinants in philosophical activity, **it may possibly be a similar if not necessarily the same urge as what Reichenbach calls the quest or search for certainty,** particularly observable in rationalist philosophers (Reichenbach, 1966; p. 31 and so on), **which makes the typical reductionist look for as simple a component as possible, The Reduciens,** if not necessarily an ultimate entity, **to account for phenomena of highly complex nature.** This we might perhaps call "**the urge to reduce**" (or "**to oversimplify**"). Although it is obviously not the business of the philosopher but of the psychologist to study the dynamics of this tendency, it would certainly be highly rewarding for the philosopher (in principle, of whatever school) to have an acquaintance with the psychological determinants, the "hidden" purposes or aims, of his or her seemingly exclusively conscious or "logical" activity.

Section 2.4.13

From a Scientific Point of View

Certain passages of this dissertation would concern the scientist possibly more than other passages, apparently because of the discussion of certain concepts in principle familiar to him. In the chapter on levels, for instance, sections on temporality, mathematicity, causality, structure and function, and on the idea of systems (sections 2.1.6-7, 2.1.10, 2.1.12-13); in chapter 2.2 on the comparison between the organic and inorganic realms, sections related to the characteristics of life and to the genetical structure and its functioning (sections 2.2.1-6 and 2.2.12-13) may be relevantly mentioned for such a purpose, as well as probably most parts of chapter 2.3 on reducibility in genetics, in particular section 2.3.4 with its mention of the scientists' (physiologists') approach to experimental research. From the viewpoint of reduction in biology, the domain of genetics could again be a good case in point with its biomolecular or microgenetical and macrogenetical or hereditary dimensions (see section 2.3.10), which I shall comparatively treat later in this section as well.

While talking about the concept of "partial reduction", the "reductive power" of a branch of science and of reduction by means of a micro-theory, Kemeny and Oppenheim mention H. Feigl's term, "levels" of explanation (Kemeny and Oppenheim, 1970). The term "**levels of explanation**" may evidently be seen, in however an approximate way, as an epistemological equivalent or rather, perhaps, homologue of the ontological "levels of organization" discussed and frequently mentioned in this thesis, and may be of interest for us from a scientific point of view. And while talking about microreductions, we might briefly mention Causey's argument that correlations, unlike identities, require explanation (Causey, 1972). I think that however technically advanced, as has been achieved by him, this kind of argument is undermined by the fact that explanation is the very basis of reductive operation, whereas "identity" or "attribute-identity" for that matter (Causey, 1972), does not seem to be a justifiable term because of the confusion it creates in the practice of science, and at whatever level of explanation at that - it is correlations that the scientist is after, not the strongly philosophy-loaded identity, between phenomena.

Another and understandably more fundamental confusion appears to be caused by regarding physics as a universal science in a sense in which others are merely "special sciences", and this has been due to the acceptance of everything bigger than a point having "properties that are physical by mere definition" and of everything moving having "physical properties"; but that does not make physical siences <u>universal</u>, in the sense of encompassing all the properties and relations of things, nor <u>basic</u>, in the sense that other sciences must reduce to them. All this would support a non-vacuous definition of the physical, as needed by physicalism, but **physical sciences such as mechanics and microphysics are no more universal or basic than, for instance, psychology is - they are merely the special sciences of motion and of the very small** (Crane and Mellor, 1990) (my bold emphasis). In other words, **sciences are different, from the point of view of reduction, insofar as their levels of explanation differ from each other.** Furthermore, it seems to be a great yet widespread mistake to confuse matter (and the related concept of energy) with what is physical; in the sense of having spatio-temporal existence, the latter term would mean "empirical" (or "pertaining to nature", as its original etymology implies) and not "pertaining to (the science of) physics" (see chapter 1.4). In such a light, the subject matter of any science, and certainly not only that of physics, is brought about by "the physical", and is both special and fundamental at the same time.

Although in science, and in biology for that matter, we study (usually if not always) isolated systems and the relationships between them (Örs, 1978; "Bernard"), it is by reference to the larger (or in-situ) context they belong to that those isolated entities assume scientific significance (apart from the "investigative urge" of the specialized scientist directed to the study of the part). This might be called **"scientific semantics"**, which is evidently complementary to the philosophical one (as discussed in section 2.4.11). According to Hempel, the characterization, by their molecular structure, of such substances in biological sciences as penicillin or testosterone, with their original definitions at the biological level ("an antibacterial substance produced by the fungus penicillium notatum", "a male sex hormone produced by the testes"), is arrived at, not by meaning analysis, but by chemical analysis; the result constitutes a biochemical discovery expressed by empirical laws, not a logical or philosophical one stated in terms of synonymy. And "acceptance of chemical characterizations as new definitions of the biological terms involves a change not only in meaning or intension, but also in extension" (Hempel, 1966). All this certainly sounds quite "logical" and philosophically as well as scientifically justifiable, but what the author does seem to neglect as **the vital point in terms of empirical semantics in science and in the philosophy of science is the biological context within which the scientist, the biochemist or any other, works (ideally, in a conscious manner) - the human organism, to which the above "chemical substances" are related, through the immune and the endocrine systems respectively, and which are biological entities, or rather subentities.**

The reduction of one discipline to another does not require that the terms of the reducing theory should be equivalent in meaning to those of the reduced theory and that the reducing theory should explain the events covered by the reduced theory **under the same description**. For instance, the consideration of disease as a normative or social concept, or of the collapse of an apartment as a disaster, is no barrier to the explanation of the former as a biological phenomenon and of the latter as a physical event (Munson, 1981) (leaving aside those factors to be involved at other levels) (my bold emphasis). Again, however, **the vitally significant point at the conceptual level and which I am determined to emphasize (although, of course, not to overemphasize) is that we have to take into account those aspects of the states of affairs, whether general or particular, to which any lower-level explanations must be related. Otherwise, explanatory formulations, however sophisticated and admirably perfect they may appear to be, would be "meaningless" or, semantically even though not logically, "vacuous".**

And in medicine, by the way, findings, that is, symptoms and signs, of "clinical pathology" can be interpreted, at our level of discourse, as the "markers" of an "internal pathology". Certain events (phenomena) in science and technology are almost always uniquely determined; that is, they are end events (phenomena) on just one causal chain with its own source, its own initial cause, and which are to be called source indicators. When the blue-litmus test is positive, one can be practically certain that it is a source indicator of acidity in the fluid tested. In modern medicine, most of the source indicators reveal only intermediate pathological events. Those which reveal pathological onsets, such as the presence of malaria parasites in red-blood cells, can be distinguished as radical source indicators (Taylor, 1979; pp. 34-35).

From a more general biological viewpoint, parts-layers and process-layers will thus become integrated as a level of systemic organization by the ontological correlations that can be drawn by them (Juengst, 1985; vol. 1, p. 116). In a rather rough or approximate manner perhaps, this seems to be the kind of correspondence or parallelism reminiscent of the distinction between the observable and theoretical entities and processes in science in general.

As in the case of part-whole relations and other elements of the systems approach, definitions of a system's concepts are very much interrelated; and a concept is meaningful only within a "system" (Pehlivan, 1982) or "network" of concepts. And (from an ontological standpoint) the concepts in the context of reduction are about what one may call real relations such as causal, identity, spatial, temporal, as well as part-whole, etc. (Beckner, 1974), all of which I have so far discussed in this work in different places and at different lengths. Bearing always in mind that the concept of structure is defined (mainly) by the terms "whole," "element" and "relation" (Puterman, 1980), it could be interestingly relevant to remember again that in the context of biology's relation to other natural sciences Warren Weaver aptly characterized classical physics as organized simplicity, statistical mechanics as chaotic complexity and biology as organized complexity (mentioned in Waterman, 1968)(see the end of section 2.4.2).

In the case of the levels of organization approach, what replaces the part-whole relationship of the general systems theory is evidently the interlevel relations, and this, in turn, necessitates a conception of levels and the recognition of the distance between them. Applying this to genetics, for instance, the systematic identification of adult and gametic characteristics would be unjustifiable, as it was to the geneticist T. H. Morgan in the beginning of this century (Manier, 1969); the distance involved here is actually brought about by molecular phenomena genetic phenomena on the one hand and on the other (Goosens, 1978), or by **the differences and relations between the phenotypes of organisms and their genotypes.** The process of metamorphosis from one essential level of empirical organization to the other in genetics is certainly no less interesting than the evolution of the field of genetics (see, for instance, Emery, 1983; pp. 1-29) itself.

I think that the concept of the levels of empirical organization is very much in tune with the essential dual aspect of the unity and plurality of science (Örs, 1984), for it incurs upon it an interscientific or interdisciplinary quality, both in theory and research, whereby each major scientific discipline and its subbranches are brought together while they still preserve their "ontological" and "technical" identity or autonomy. To the extent that philosophers take reduction for granted and even consider it somehow anti-scientific to seriously question it (Dupré, 1983), to that extent they will apparently fail to contribute to the critical conceptual clearing of the ground in their guidance to the scientist. It may roughly be said that while the latter is basicly concerned with the explanation of phenomena, the former is in quest of a critical logico-semantical analysis of this explanation, which, at their respective level of interpretation, assumes the nature of what we call reduction. Thus, though they intersect or overlap inescapably, science and philosophy assume appreciably different roles in the matter of (explanation and) reduction.

We shall consider the matter, that is the relationship between reduction and explanation, from a somewhat different point of view in the next and last section of this chapter. A very general remark at the end of the present section could be about the confusion as regards the two activities just mentioned - while reading Reichenbach's book on Scientific Philosophy, a colleague of mine said: "it is science, not philosophy." Finding scientific terms in a work of (and on) philosophy, and in his apparent effort to oppose the traditional speculative philosophy, he was going so far as denying philosophical activity altogether.

Section 2.4.14

From one Philosophical Point of View: Supervenience

The rather recently developed concept of Supervenience has begun to be reflected in the philosophy of biology (and psychology), because the concept of Causality, particularly in its narrow sense of "cause-effect relationship", has apparently seemed to be too strict in terms of empirical semantics - the "real" states of affairs, that is, whatever indeed occurs in life systems and the related levels, and so far as the relationship between the biological and the physical (in the general sense of the term) is concerned, have generally appeared to be too complex to be accounted for by any known reductive operation with Causality or Causal Connection at its center. Even those accounts that have so far been "successful", such as the one in genetics, seem to be highly controversial as the related literature shows us; and even most of those philosophers (and the philosophically minded scientists and historians of science) for whom an almost "full" reduction is possible in principle are not always so insistent on their views, beacuse not a few "sceptical" questions as to the reduction in biology in terms of the received view remain to be unanswered, as the above account, I think, must have shown.

We might perhaps remind ourselves of the fact that **whether in terms of causality, supervenience, reduction, explanation or any other, separately and/or jointly, all the accounts to find a relationship between the "biological" and the "physical" are attempts at finding determinative connection(s) between two sorts or two sets of phenomena.** (Even when the relationship appears to be of a basicly or predominantly nondeterminative nature, it seems certain to me that we must have recourse to the concept of determinism, at least to be able to appreciate the dialectical dimension, so to say, underlying the connection - see section 2.4.10.) Earlier in this work and relevantly in this context, whether directly or indirectly, we have discussed, for instance, such topics as the interfield theories in connection with reduction (section 1.3.10), historical unification and the logical unity of science (section 1.3.11), analysis and reduction (section 1.3.12); deductive preservation and radical unrepresentability in theory reduction (section 1.3.13); type-type and token-token reductions (section 1.3.15); causality in the contexts of levels, teleonomy and genetics, and reduction and explanation (sections 2.1.10, 2.2.10, 2.4.10, respectively); and structure and function in relation to the concept of levels (section 2.1.12).

The concept of supervenience seems to have originated in the writings of two moral philosophers, G. E. Moore and R. M. Hare (to the latter the coinage of the term is due): While moral concepts such as being a good person or being a right act are not definable or reducible in terms of naturalistic or descriptive properties, the former are said to be "supervenient" on (or "consequential" upon (Kim, 1978)) the latter in the sense that any two persons, acts, etc. that are exactly alike in respect of descriptive or naturalistic properties must also be alike in respect of moral or evaluative properties. Put differently, once the descriptive or naturalistic properties of a given object are wholly fixed, its moral and evaluative properties are also thereby fixed (Kim, 1984a). More recently, the concept has been increasingly used in other areas of philosophy, above all (and expectedly I think) in the mind-brain problem and in the form of psychophysical supervenience (Kim, 1984a); in the field of aesthetics (Gillespie, 1984); and in the problem of theory reduction in the philosophy of science generally (Horgan, 1978).

Central to the idea of interconnectedness of things (processes, properties, and so on) is a notion of dependence or, its converse, determination: things (or all the ontological units) are connected with one another in that whether something exists, or what properties it has, is dependent on, or determined by, what other things exist and what kinds of things they are. And causation thereby becomes a preeminent example of what J. Kim is calling determinative or dependency relations (Kim, 1984b).

A very significant aspect of the concept of supervenience **as to the determination-dependency relations in the empirical world** is the **kinds of supervenience formulated in accordance with the degrees of such relations expectedly existing between the entities, properties, and so on, involved.** In one form, for instance, "A weakly supervenes on B if and only if necessarily for any x and y if x and y share all properties in B then x and y share all properties in A - that is, indiscernibility with respect to B entails indiscernibility with respect to A" (Kim, 1984b). In this **weak supervenience**, A is called the supervenient family and B the supervenience base (family); properties in A are supervenient properties, while those in B are the base properties. In a strengthened form of weak supervenience, "A weakly supervenes on B if and only if necessarily for any property F in A, if an object x has F, then there exists a property G in B such that x has G, and if any y has G it has F." Although the two definitions of supervenience are equivalent and entail each other, the stronger form requires that any object having G also has F, but does not require that the G-F connection be stable across worlds. In order to get a (still) stronger supervenience relation which will insure the stability of connections between supervenient properties and their base properties, one should try prefixing this clause with a suitable modal operator, such as "cannot" given (by Davidson) in the following example: "an object cannot alter in some mental respect without altering in some physical respect" (Kim, 1984b).

In what is called **strong supervenience**, "A strongly supervenes on B just in case, necessarily, for each x and each property F in A, if x has F, then there is a property G in B such that x has G, and necessarily if any y has G, it has F." A supervenient property will have, generally speaking, alternative supervenience bases - base properties that are each sufficient for the supervening property. It will be seen that while strong supervenience entails weak supervenience, weak supervenience does not entail strong supervenience (Kim, 1984b).

Furthermore, we have what is called **global or world supervenience** in which "A globally supervenes on B just in case worlds are indiscernible with respect to B ("B-indiscernible", for short) are also A-indiscernible." In the light of this, psychophysical supervenience has been explained by stating that worlds that are physically indiscernible are psychologically indiscernible, such worlds becoming in fact one and the same; and moral supervenience by saying that there could not be two worlds that are indistinguishable in every nonmoral detail and yet differ in some moral respect. Kim argues further that while global supervenience is stronger than weak supervenience, it is equivalent to strong supervenience (Kim, 1984b). In a more recent article, Kim has re-analysed strong and global supervenience, and given a new characterization of the former and "strengthened" the latter (Kim, 1987).

While other writers, too, have considered the formal as well as nonformal, mainly empirical aspects of the concept of supervenience in different contexts (see, for instance, Bacon, 1986; Bonevac, 1988; Cleland, 1984; Horgan, 1981; Klee, 1984; Rott, 1987; Seager, 1988), what we are mainly concerned with here is understandably its relation to the concepts of explanation and reduction, and however sketchily it may be. We may also have a chance, while doing this, to view the topic in its relation or application to reduction in biology.

Quite interestingly for us I think, B. Petrie argues that while global supervenience is not equivalent to Kim's strong supervenience, it possesses a number of features which seem to make it particularly well suited to characterizing the relationship between physical and nonphysical properties required by physicalism. Because it allows, among other things and unlike other, non-global versions of supervenience, for the holistic manner in which many non-physical properties are determined by their physical environment and for reconciling the complete physical determination of non-physical properties with the apparent irreducibility of many of these properties to physical terms (Petrie, 1987). P. Teller, on the other hand, tries to explain that "supervenience is not just disguised reduction"; otherwise, it would loose all its (philosophical) interest (Teller, 1985). Harold Kincaid is evidently one of those philosophers who appears to have a systematic interest in the topic of supervenience and its relation to reduction and explanation. One of his conclusions is that determinism on its own does not entail supervenience in the biological realm, because it seems entirely possible that as a matter of logic two systems, in this case the biological and the physical-chemical, can be deterministic yet entirely independent; unless, of course, supervenience or some related principle is true (or if we take it for granted). On the other hand, even if it does not follow from determinism, the supervenience of the biological upon the physical is a reasonable assumption. The point is that in biological contexts (at least) supervenience on its own does not entail reducibility, whatever the respective lower- and higher-level theories may be (Kincaid, 1987).

Kincaid quite rightly points out that the connection between supervenience and explanation lies at the heart of many crucial issues in the philosophy of science. In his view, with which I wholly agree, our conception of scientific unity will have to be much more subtle than reductive accounts imply. Unlike the eliminativist programs (or accounts), whether supervenience guarantees explanation is an empirical question that can only be answered by a close look at the special sciences which would have an autonomous role in explaining the world, a role that is not entirely pragmatic in nature. Once serious doubts were raised abut reducibility, those with reductionist tendencies were forced to argue that although higher-level theories were not reducible to lower-level accounts, lower-level theories could nonetheless fully explain all higher-level phenomena - they could do so by fully explaining higher-level events (phenomena) in terms of the lower-level events (phenomena) upon which they supervene. Such lower-level explanations, called by Kincaid supervenience explanations, were assumed to be possible and fully adequate regardless of theory reduction. (I think that we do not have enough space here to critically discuss the neglect of theory-ladenness in such accounts which may be seen as a serious epistemological gap.) He considers cases from different special sciences such as sociology, psychology and biology. In the latter realm, supervenience explanations of cell biology in molecular terms face real obstacles because many important cellular processes and components are described functionally. On the one hand, in this case, functions are frequently prone to multiple realizations - when cell biologists say that signals are recognized by receptors on the cell surface and the message is then amplified, converted to a second messenger and transported to the appropriate place in the cytoplasm, they are describing general processes that might well be brought about in indefinitely many ways. On the other hand, potential molecular accounts of cellular information may presuppose cellular information (**empirico-semantically**, on my account) as in the case of protein transport in the cell which often comes about by a "signal sequence", that is, by a special combination of molecules that are attached to the protein itself. As many different molecular chains can serve as signal sequences, "signal sequence" may have to be functionally (and not just reductively) defined. More examples like this would lead to the conclusion that disjunctive supervenience explanations of cell phenomena will not be completely adequate (Kincaid, 1988).

Earlier, in relation to supervenience, J. Kim discussed "mereological determinism", microphysical determinism being a form of it. A property may be said to be "mereologically determinate just in case if anything x has the property, there is a set of "mereological properties" of x, that is, properties belonging to proper parts of x, such that if anything has these properties it, too, would have the property in question. Mereological determinateness, therefore, is tantamount to supervenience upon mereological properties." In this determinative part-whole relationship, as Kim puts it, "much of our thinking (...) seems deeply rooted in the Democritean credo that wholes are completely determined, causally and ontologically, by their parts, that if you make a replica of an object by putting it together atom by atom, particle by particle, you get the "same" object." However, mereological determinism does not imply atomism, nor does it imply that all properties of the basic particles are "physical" in a nontrivial sense - they are physical in the uninteresting sense that they are instantiated by these basic particles which presumably are physical entities (Kim, 1978) (cf. Chapter 1.4).

In his revised version of global supervenience which I very briefly mentioned above, Kim formulates his new, similarity-based concept of global supervenience in the following way: "The degree to which any two worlds are similar in respect of B-properties is matched by the degree to which they are similar in respect of A-properties" (Kim, 1987). This more tolerant version of the concept of (global) supervenience seems to me much better suited to the realistic requirements of the philosophy of science, and to the demands of our specific topic, reduction in biology. The concept of 'fitness', for instance, is supervenient on the manifest properties of organisms, their anatomical, physiological, behavioral, and environmentally relative properties - a fact explaining the simultaneous explanatory power and empirical recalcitrance of the concept of fitness. The flexibility which supervenience affords here, and the consequences of the nature of fitness in this account for the interaction of the theory of evolution and other theories, also enable us to state the claims of the reductionist with respect to popular genetics and molecular genetics in a brief but precise way. In the case of genetics, the relations between Mendelian predicates and molecular ones or, to put it ontologically, between Mendelian genes and DNA sequences, may indeed be many-many (Kincaid, 1988; Rosenberg, 1978), and this does not make for the impossibility of identifying (or, on my account, finding the correlates of) types of transmission genes and molecular items (Rosenberg, 1978). Let us not forget, however, that when we have a many-many relation between higher- and lower-level kinds, then there is no obvious way for supervenience explanations to capture the content of some given higher-level kind, "for there is no unique and single lower-level kind that will serve that purpose" (Kincaid, 1988).

It may be interesting to learn the findings of Lettvin and Gesteland (in 1965), two biological researchers, on the frog's sensory organs, the eye and the olfactory apparatus. They have found, in connection with the latter, that the response of a single axon in the olfactory nerve is not odor-specific - it does not discharge only when a particular chemical and its related compounds are wafted into the nose. While specific receptors of that sort exist elsewhere, they have found no analogous elements in the frog's nose, and almost every odor seems to affect almost every receptor one way or another (Goodfield, 1974).

The challenge of such empirical findings in the matter of supervenience and reduction must be rather obvious. Supervenience is stronger than the trivial claim that everything extended in space has physical parts; it is, however, weaker than reductionism since it says nothing, for instance, about which non-mental difference will accompany any mental one; that is to say, it does not entail the existence of any psychophysical laws (Crane and Mellor, 1990). I think that the situation would not be appreciably different in the case of biological supervenience and biological reduction - we could indeed replace the terms mentioned above by "non-biological difference," "any biological one," and "any biophysical laws".

I think we have no more space here, and presumably no sufficient rationale either, to make a full comparison between the reduciens, explanans, and the supervenient properties on the one hand, and, on the other, the reduciendum, explanandum, and the supervenience base (or the subvenient (Gillespie, 1984)) qualities. We might perhaps remind ourselves of the fact that whatever further scientific research and theorizing, and above all the related philosophical inquiry may reveal, the network of propositions involved in reduction and explanation and in the quest of supervenience will possess, as (direct or indirect) empirical statements, the overall characteristics of intersecting or overlapping generalizations about the empirical world with the essential impossibility of drawing sharp demarcation lines between them. The principle of finite classes assures us that any statement of biology is a specialization and not a generalization of the content of physics, with the justifiable conclusion that no logical contradiction between biology and physics (and chemistry) is ever possible (Elsasser, 1981). And I think this means, by way of implication, that the reductive relationship between the two realms must be based not on basicly formal but on empirico-semantical (in a sense, jointly "scientific-philosophical") grounds.

PART THREE

IMPLICATIONS IN RELATION TO CERTAIN PHILOSOPHICAL CONCEPTS

Introductory Remarks

As I mentioned very briefly at the end of Introduction and Presentation, this Part of the work will be devoted, in a rather summary form though, to what might be called a consideration of the possible general implications of the foregoing discussion; essentially of those implications which could meaningfully be related to the content presented earlier, and above all, to be sure, so far as the concept of reduction is concerned. Some of the underlying concepts of these implications (causality, determinism, emergence) have already been discussed in some detail in the related passages so far, while others (evolution, those relatable to ontology and classification) will be stressed in the context of the short chapters of the present part.

As mentioned earlier, again, and as must be seen from a glance at the chapter headings, some of the concepts to be dealt with in the passages to come are of general philosophical interest while others are evidently basicly or predominantly biological. In any case, they shall be treated in the understandably limited space of the present context (which is part of a more or less special topic) neither in a comprehensive manner nor too narrowly and from the point of view of the specific context of the present work, namely, reduction in biology. Overall, and depending on the concepts in question, I intend to consider them in an area in between, centered mainly but not exclusively around the topics of general biological, above all evolutionary, significance.

From the very beginning of Part one to the end of Part two, I have tried to replace more and more the descriptive-illuminatory considerations by a more or less critical-argumentative discussion, although I have certainly not been able to do so in an uninterrupted and regularly unfolding manner. In the last though expectedly shortest part of the dissertation, I do intend to keep in mind that a basicly critical approach to the concepts in question must dominate their treatment. Another concern of mine will be the emphasis, whenever possible and whether directly or indirectly, on the concept of levels and its central importance as regards the topic of reduction (in the philosophy of biology and in philosophy generally).

Following the "summarizing" overview method of the earlier related material in the beginning of every section in the previous chapter, I shall very briefly mention certain earlier related sections in the introductory paragraphs of the following four chapters of the final part.

Chapter 3.1

CAUSALITY AND DETERMINISM IN THE LIGHT OF REDUCIBILITY

I have discussed the concept of causality particularly in its relation to the idea of levels (section 2.1.10); in the context of the teleological or teleonomical characteristic of living systems (section 2.2.9) and, in addition, of their genetical properties (section 2.1.10); and certainly also, in connection with reduction and explanation (section 2.4.10).

In roughly the second half of Chapter 2.4, with its title "Reduction as a Form of (Partial) Explanation", the topic of causality and the closely related concept of determinism have been variously discussed in their relation to the operation of reduction. In section 2.4.10 particularly, determinism and causality have been considered with a view to the clarification of reduction and explanation in philosophical terms. The term "reductive operation" implies, obviously and to the extent that it can be done in philosophical practice, the possibility of its realization, that is, **reducibility**. Leaving apart the degree of its success in different domains of philosophy and in the philosophy of different sciences (and even their subbranches, subdomains, and so on), it appears that **the operation of reduction is based**, both ontologicly (or indirectly through sciences) and epistemologically, **on an attempt at finding a relationship between two (or more) sets of related or (scientifically) relatable phenomena or regularities (entities, processes...) in the empirical world. And in the empirical or spatio-temporally perceivable and intelligible world it seems that the relata** (signifying the phenomena at both ends of the relationship) **can only be conceived and philosophically** (and scientifically) **studied conceptually-operationally in connection with such concepts expressing relationality as causality and determinism (and possibly indeterminism and dialectics).** And these latter concepts should be based, in turn, and in congruence with philosophical realism, on their ontological counterparts in the form of "**empirical principles**" (of causality, determinism, and so on). It may be stressed, I think, that both epistemicly and ontologicly, **terms expressing regular or constant** (universal and/or statistical) **connections between phenomena such as causality or determinism would assume their philosophical role in a more conspicuous manner when they are seen in the light of the concept of reducibility, hence explainability; because in spite of the ongoing controversy on the relationship between these two latter concepts, they appear to be the most essential methodological and operational tools at the disposal of the critical-semantical inquirer of the philosophically significant products of science, theories and laws in our present context.**

As I have frequently stressed, the complexities of biological systems would prevent a wholesale or almost wholesale deduction of comprehensive biological laws from the laws of chemistry and physics; the multitudes of alternative possibilities, ranging from man to mosses to "silicon-based biologies" inhabiting seas of ammonia, prevent deductions of specific forms or processes from "fundamental" laws alone. In certain cases of circumscribed, well- formulated phenomena, clear and quantitative relationships to molecular processes may be established, as has been realized by Huxley when he explicitly related his biochemical model to Hill's measurements of heat generation during muscle contraction (Robinson, 1986) (my quotation marks). In the words of Hempel, "the construal of theoretical reduction as a strictly deductive relation between the principles of two theories, based on general laws that connect the theoretical terms, is indeed an untenable oversimplification which has no strict application in science and which, moreover, conceals some highly important aspects of the relationship to be analyzed" (Hempel, 1969).

On the other hand, in an article on "Explanation and Prediction by Covering Laws", Hempel proposes two covering-law models of scientific explanation: the deductive-nomological, or briefly the deductive; and the inductive-probabilistic, or briefly the probabilistic. Basing both of his covering-law models on a nonpragmatic conception of explanation, he considers scientific research as seeking an account, both descriptive and explanatory, of empirical phenomena which is objective in the sense that its implications and its eventual support do not depend essentially on the individuals who happen to apply or to test them. And he argues, on the grounds he has discussed, that one can dismiss the complaint that the covering-law models do not, in general, accord with the manner in which working scientists actually formulate their explanations (Hempel, 1963). Even in that case, however, both the philosophically minded scientist and the philosopher of science should apparently be in a position to know that inter-theoretic reductions are distinctive scientific accomplishments of very different kinds. There are homogeneous and inhomogeneous reductions; 'total' and merely 'partial' ones; some are simply derivations, others elaborate identifications. Even more interestingly, it seems, some reductions provide deeper confirmation for the reduced theory, while others serve to eliminate the reduced theory as a viable competitor for the status of scientific truth in the very act of reducing it to another accepted theory. However, according to L. Sklar, the fact that for all their similarities reductions are a very diverse bunch of items to come under a single name "should neither surprise nor disturb us so long as we do not let the convenience of the use of one 'family name' lead to obfuscation by equivocation" (Sklar, 1967).

One corollary or implication of these views would apparently be such that we might need a comprehensive and more systematic consideration and ensuing account of reductive operations in different areas of the philosophy of science and in those of philosophy in general (so far as empirically oriented inquiries are concerned); such a "pluralistic" understanding of and a related basic approach to reduction, particularly inter-theoretic reduction, have clearly been stressed, whenever occasions arose, in the present work. In terms of ontology, the most significant if not sufficiently operational conceptual tool seems to be the concept of the levels of organization, with the distances and interrelations involved as regards the empirical world.

As we have seen in the last section of Part two, **Supervenience** has recently become a very significant or key concept in the attempts to explain the relationship between the relata in reductive operations in the philosophy of science. As D. Bonevac succinctly though somewhat oversimplifyingly expresses, the logical empiricists were correct to emphasize the ontological unity of science and the primacy of physics, but they were (possibly) wrong to rely on reduction as the only way to establish intertheoretic relationships. In his view, in our attempt to keep the logical empiricists' ontologically parsimonious conclusions without committing ourselves to the drudgery of outlining the "logical" structure of the world, the concept of supervenience, relating closely to our ordinary idea of dependence, seems to provide an ideal answer. Generally, one realm - of properties, facts, and so on - supervenes on another just in case the latter determines the former, that is, the constitution of the former is a function of the latter (Bonevac, 1988) (my quotation marks).

This view seems to agree, possibly not directly though, with Kincaid's thesis that supervenience does not entail reducibility, as I mentioned in section 2.4.14. The logical wedge that remains between supervenience and reducibility, and the question of whether there is in fact such a gap awaiting a closer look at the special sciences (Kincaid, 1987) should deserve our attention in two respects. First, such a "logical gap" exists because, from a very basic philosophical point of view, **the term "supervenience" above all expresses an ontological and not operational relationship, that is, one which is already there prior to our epistemological endeavour; whereas "reducibility,"** as the suffix must suggest and as it has been considered in this work, **is an empirico-logical, that is, epistemological term.** Secondly, and as, again, must have been clear so far in this dissertation, I hold, as do Hull (1976) and Sklar (1967) for instance, that **an all-inclusive formulation of reduction that would be functionally valid for almost all theoretical (and/or "nomological") reductive operations in and between sciences**

appears to be an untenable quest; it is perhaps defendable on psychological rather than empirico-logical grounds (see section 2.4.12).

Although the non-physical supervenes on the physical (in the sense, "as related to physics"), explanations in the (so-called) special sciences are not always underwritten by physical explanations (Neander and Menzies, 1990). And in the case of reduction of the biological to the physical, the concept of supervenience must apparently if not necessarily be treated together with evolutionary considerations, particularly because of the highly relevant topic of emergent properties.

Chapter 3.2

REDUCIBILITY SEEN IN THE LIGHT OF EVOLUTION

While the levels and their organization (section 2.1.2) is to be considered in the light of **the notion of temporality** (section 2.1.6), **the concept of emergence** (section 2.1.5) is evidently the key idea uniting the two in terms of such basic empirical principles as causality, determinism, dependence, structuring, supervenience and perhaps one or two others; we have considered them in the relevant passages above, either immediately or earlier. In the biological realm, it is because the history of organized structures (Gutman, 1964), and of ontological units of existence as a whole (properties, processes...), becomes so significant an issue that the theory or perhaps rather **the concept of evolution** comes to the fore. **Historicity**, separated semantically from the usual sense of the term "history" with its core orientation to events as special happenings rather than to phenomena which are repeated occurences, **would strongly suggest Evolution** as a general flow of empirical states of affairs. In such a dynamic flow, causes, factors and conditions of emergent qualities, in short determinants of phenomena as a whole, supervenience and structuring and other possible empirical expressions of relationality (in temporality) have all to be, and ontologically are all indeed, of a general nature - they are earlier phenomena, or earlier products of emergence, preceded still by others, and up to a point of beginning where we have to stop. Also, certainly, to be followed by others as products "of their own", because the process of evolution is evidently an ongoing, incessant flow - to be stopped only in case of an overall or nearly overall disappearance of the determinants.

Such a multi-aspect or many-sided approach to the process of evolution could open new vistas in front of us, one of which, namely that of reduction, understandably being the most relevant topic in the present context. And this topic might bring in its wake others of almost equal philosophical interest.

Seen in the light of an evolutionary flow, or simply evolution, and of the concept of regularities, it must be quite obvious, **empirico-logically and at first sight, that the set of reduciens as determinants should come or should have evolved earlier in the flow than the related or corresponding reducienda which are their product. The same must and can be said of the supervenience base or subvenient properties in their temporal relation to the corresponding evolutionary supervenient qualities. And the temporal order in the evolutionary flow should also be the same between the (micro-)determinant(s) and its (their) effects or products as the components of a relata or explanans-explanandum complex.** I wonder if such an approach could not provide a support, in terms of a dynamic ontological-epistemological consideration, for an overall concept of evolution (leaving aside a would-be vicious circle that would arise in the case of an analytical and rationalistic treatment of certain temporally related concepts and views - in the present case, evolution, reduction and reductionism).

If higher-level kinds are realized in lower-level states that are quantitatively characterized, as Kincaid explains aptly, then there may well be an infinity of possible physical realizations as in the case of, for instance, the supervenience relation between fitness of higher-level biological kinds and such characteritics as strength, speed, metabolic capacities, etc. (Kincaid, 1988). Seen in the additional light of **what we might call entrenched regularities** or what is already called "selected-effects" theories (Cummins, 1975), **any possible realization**, physical, physicochemical... biological, and so on, **must have resisted to elimination in the course of the evolutionary flow and must have been stabilized in terms of evolutionary time scale.** And **what we observe "now" as realizations such as entities, relations, processes and other forms of ontological units have been the products of the evolutionary "ordeal",**

preserving the time order between their temporally related components, such as we see in reduciens-reduciendum or part-whole relationship. Under the normal circumstances of regularity, the determinative relation appears and appears again, and again, and so on incessantly (with some possible modifications maybe), extending from the evolutionary past to the contingent future via the "observable" present.

At the very begininning of his work on "Chance and Necessity," with its subtitle, "An essay on the natural philosophy of modern biology," J. Monod gives a succinct quotation from Democritus: "Everything existing in the universe is the fruit of chance and of necessity" (Monod, 1971; p. v). In my own and apparently more comprehensive approach, and which is complementary to the above one, I would say that in an extreme summary form we could formulate the following equation: **Evolution = Change plus Continuity**. While Democritus has apparently stressed the determinative aspect of the flow, the latter "formula" underlines, I think, its overall ontological characteristic with an emphasis on the temporal dimension.

I do not intend to elaborate here either of these obviously interrelated aspects of the concept of evolution, but one or two relevant points could just be mentioned. The questions of "why?" and "how?" in relation to scientific explanation and reduction (Kincaid, 1988; see section 2.4.10) could be meaningfully and justifiably asked in the context of the concept of evolution. One of the reasons for this is obviously the fact that the first question is intimately connected with the problem of teleonomy. But its directly "neutral version" as well as the second question, too, could be functionally discussed in relation to temporality and so far as this can be done within the joint context of reduction and evolution. Not only a simple why-question (Kincaid, 1988) but also how-questions must apparently be evaluated from such standpoints as ambiguity, the expectation of the relevant kind of answer, and the consideration of the background theory.

Although **why-questions** as a rule imply a quest of determinants in connection with their supposed effects or products, and **how-questions** suggest an expectation, an account as to the stages of occurences, or mid-occurences if you like, that connect the determinants to the temporally end-product, it appears that both types of questions do have points in common. Particularly in very complex "cause-effect" relationships such as we observe in biomedicine, in infectious diseases for instance, **the "how" or the "mechanism"** of the overall phenomenon or process, including the temporal order as well, cannot be kept apart from the microorganism(s) and the contributory factors involved as determinants of differing degrees - in such instances, **the cause or "causes" significantly determine the mid-occurences, hence the outcome, the latter evidently not being independent from the former** (the diaerrhea caused by the cholera agent and potentially leading to death). **Conversely, the why- or cause-question is related to the effect in question by way of what occurs in between, that is, through the mechanism.** As for a more direct application of these and similar points of determinism on to the occurences that take part in the course of evolution, we have obviously too little space for it in this context. But certain remarks can be made in the matter of evolution insofar as it is related to the matter of reduction.

In this regard, one of the main topics is that of **Emergence**, which we have considered in several contexts earlier. In terms of the "birth" of new ontological or empirical units in the world, such as new species with their new characteristics, more or less new relations and new processes, evidently all these and similar unprecedented comings into being in evolutionary flow would represent, and must certainly be seen as, **emergent phenomena. When they reach a sufficient quantity as entities, properties and so on, and with an adequate level of stabilization, that is, assuming the form of regularities or recurring phenomena, they have become established parts of the evotionary flow (until, of course, they have disappeared either by means of mutation and replacement or through extinction). Emergence, then, is**

__evolutionary change in a forward or productive sense__ (in contrast to regressive evolution with the extinction of organs, species, and so on).

Having already done so in the related sections and passages, I shall not dwell here on the question of whether emergent qualities are reducible to the lower-level empirical properties in a strict sense. **In the sense that reduction in epistemological-semantical terms is a partial explanation, there seems to be no reason why anything that emerges should not be reasonably accounted for by, hence would not be reduced to, the already existing ontological units so far as the two sets can be scientifically related.**

The concept of emergence certainly forces our concepts of causality and determinism, hence that of reduction. But for instance, seeing emergence as the appearance of additional characteristics upon the already existing life, and at the same time regarding animals as physical systems being products of evolution (Fong, 1968), must basicly be due to a lack of an overall understanding of reduction.

Chapter 3.3

DIFFERENTIATION (DIVERSIFICATION), EXTENSION, EMERGENCE

In different sections and so far as would be necessary for us in the present context, I have tried to enumerate, so to say, the basic characteristics of living entities or systems (sections 2.2.1-2.2.4, 2.2.6). In addition, I have briefly touched on the topic of genetics, in a descriptive manner (sections 2.2.11-2.2.13) as well as from the point of view of reduction in biology (sections 2.4.4-2.4.6). Thirdly, I have discussed the issue of teleonomy in biology in its relation to genetics and reduction (sections 2.2.10, 2.4.7). I have also stressed the importance of the concept of levels within the context of an overall relationality and complexity (section 2.1.14) and in its relation to heredity and genetics (2.2.14). And lastly to be mentioned here, I have made attempts to clarify the concept of life in the light of the notion of family differences (section 2.2.5), and to answer the question of whether anti-reductionism (in biology) is necessarily a conceptually undefendable stance (section 2.4.9).

That evolutionary theory is possibly the fundamental theory in biology and that all other biological theories must be brought into accord with it (Hull, 1978) seems evident to me, above all because of its most comprehensive spatio-temporal dimensions. One of the questions that is of interest to the philosophers of biology and the philosophically minded biologists is the "nature" of natural selection - whether, for instance, it is selection of objects or selection for properties that would matter in the last analysis ("Discussion," 1986). For our purposes here, what would matter could be the question of what "ultimately" evolves in the course of time - living entities, their properties, relational properties, the related processes, and so on. Conversely, I think that the issue of what endures or preserves its identity in the evolutionary flow would also be of real philosophical interest.

In the present context, my attention will understandably be focused on the concepts mentioned in the title and one or two related ones. To begin with, the terms "differentiation" and "diversification" may seemingly be used interchangeably, for "practical purposes" at least. But while the latter has possibly a larger scope and philosophical connotations, the former appears to be the term of choice for biologists; it is apparently their entrenched term to express the increase and cumulation in the structural and functional complexity of living systems and their parts, particularly so far as their embryological development is concerned. Out of a single cell, the fertilized ovum, a very complex whole, the phenotype develops through very many embryonic steps. And **through the complexification of species are brought about what may be called the evolutionary counterparts of the products of embryonic differentiation such as tissues and organs.**

The products of differentiation are certainly not just sets or collections of entities, properties, and so on, but structurally and functionally "meaningful" wholes. Indeed, **differentiation is systemic organization, comprising entities, properties, relations, processes in their full connection with one another. Possibly, it may also be seen as extension, extension both in space and in time, hence in space-time.** The temporal dimension incorporated into the semantics of the term "extension" is apparently quite significant and possibly modern, at least systematically modern. It seems possible that the notion of extension as considered here in a temporally dynamic fashion could possibly be applied, in a more systemic, to such immensely complex matters in biology as embryological differentiation and evolutionary complexification. But this is certainly an issue that could only independently be considered in full.

As regards temporality in its relation to very complex biological processes, an example could be given from developmental neurobiology. There are certain interchangeably used terms in this area, such as critical period and sensitive period, which refer to a period during which the nervous system is highly malleable; vulnerable period, susceptible period, and optimal period have also been proposed for this malleability. Implicit in the description of such periods are the inferences that specific critical conditions or stimuli are necessary for, and can influence, neural development only during that period. Applied for a wide range of phenomena, these terms have also been used in behavioral research, psychology and psychopathology in general, and in psychoanalysis. Reflecting the activity of multiple organizational processes, reversibility of the related effects during these periods in the adult, that is the flexibility versus the rigidity of the organization, seems to depend not only on the type of deprivation and the system involved but also on the complexity of the final organization (Erzurumlu and Killackey, 1982). My reason of mentioning this evidently interesting biological point is expectedly not due to its scientific significance but because I find it highly interesting from a philosophical point of view. To put it very briefly, I wonder how a strict biological reductionist would consider it in terms of inter-theoretic (or other) reduction, for the concept appears to be highly challenging so far as reductive operation is concerned.

If, from a reductionist standpoint, the 'evolutionary problem' is not how natural selection got started but how a certain peculiar chemistry is possible (Olding, 1985), we must also find the answer of why the chemistry of life is so peculiar. **The evolutionary metamorphosis of the process of life manifests itself in the ever-increasing complexification and diversification of the organization of living systems** (see, for instance, Huxley, 1963; pp. 38-39, for the irreversibility of evolution), **and is in philosophical terms approachable by means of an understanding of the process of emergence.** In this perspective, I think, **emergent evolutionism** (Goudge, 1967) **is the idea of evolution** (in the "productive" sense, as mentioned at the end of the preceding chapter).

Chapter 3.4

APPARENTLY POTENTIAL ONTOLOGICAL IMPLICATIONS AND PROBLEMS OF CLASSIFICATION

One could possibly mention several sections whose contents would be more or less directly related to our present context. However, not to give too much burden of relationality to the evaluators of the work in this final chapter, I want to refer to just one of these sections. When I was discussing **the relation between the levels of organization and the ontological units of the world** as I am inclined to conceive them, I pointed out that (conceptually speaking) all the five ontological units we can so far think of, namely, entities, properties, relations, steady states and processes, can be considered either intralevelly or from an interlevel standpoint (section 2.1.8). And I also discussed in that context, very briefly though and from the point of view considered there, **the futility of searching for a** fundamental entity as the ultimate constituent of the world, at which philosophers have made so interesting attempts in their ontological quest as part of their basicly speculative activity. **Emergence** is another topic I touched upon in its relation to the subject matter of the said section, and which I am planning to consider further in the present chapter so far as its relevance to its content is concerned.

The matter of ontological constituents and classification as regards the empirical world must have always been a point of high interest to the "philosopher of ontology" and the "philosopher-scientist" as well as to the men of science (for a thorough historical-philosophical survey, see Gilson, 1972 and Leclerc, 1972). The relevant aspect for our purposes here seems to be allegedly the most general, if you like "philosophical," units of the world's ontology. Among the philosophers interested in it, Aristotle would certainly be the first name to be taken into account - his well-known concept of Natural Kinds was distinguished from the three other varieties of kinds, namely, dependent, real superficial, and hybrid kinds. And according to T. E. Wilkerson, the members of natural kinds are characterized by "real essences, intrinsic properties that make them members of the relevant kind," and such real essences "lend themselves to detailed scientific investigation". The view of John Stuart Mill as regards this topic may be interesting and relevant for us because he did not posit an ultimate "real essence"; natural kinds are understood by him (and by Wilkerson) as based on strong affinity and deep similarity (Meyer, 1989).

What was ontologically important for Descartes, on the other hand, was that matter, and thus also the body, is exclusively characterized by extensiveness in space and has merely quantitative aspects; in his view, qualitative definitions do not apply to matter, and every natural phenomenon manifests itself according to the laws of movement, that is mechanically (Ten Have, 1987). Leibniz among the philosophers of the modern period seems to have endorsed a kind of reducibility thesis about inter-monadic relations ("monads" being his "ultimate" ontological units); but the issue is obscured by a lack of clarity on the part of Leibniz and his commentators (Cover, 1989). And Hume, for his part and in an interestingly (though perhaps indirectly) relevant way in our context, seems to have developed a doctrine called "Humean supervenience" by D. Lewis, and which is concerned with imaginary cases including such kinds as rotating perfect spheres or discs, and flowing rivers, imagined as composed of moving matter that is perfectly homogeneous right down to the individual points (Robinson, 1989).

I shall presently take up the matter of supervenience as an operation. Before that, however, I would like to give my own account as regards our very basic mentally operational approach to the world's ontology, that is, classification. The main questions in relation to this very general operation of ours are: "**What do we classify?**", "**How do we classify?**", and "**Why do we classify?**" (İnam, 1983). These are apparently methodological questions to be asked in the case of any significant human activity, professional or otherwise. In science, for instance, and as regards the first question, we classify subatomic particles in physics, simple and complex elements in chemistry, rocks in geology, species in biology, diseases in medicine, social institutions in sociology, and so on. As the classificatory process goes further and becomes subtler and subtler, the classification of that section of the world's ontology in a certain scientific activity oriented to the related levels of organization would evidently necessitate an increasingly closer acquaintance with what constitutes the subject matter.

As for the second question, the "method" or "technique" of classification apparently lies in the categorization or division of the subject matter according to the properties of the particulars, and sets and subsets of particulars in question. Implied in this is certainly the process of abstraction and the recognition of universals, for it is by virtue of common characteristics of whatever we classify that we form classes, and by dint of their differences or different characteristics that we distinguish certain ontological units from others. The choice of similarities and differences to be taken into account is very much dependent on the purpose of our classification, and is obviously of a basicly pragmatic nature, but "pragmatic" in a deep sense - a human being is a social entity, a biological system, a biomolecular complex, a physical object, and so on, as the case may be.

The matter of choice would bring us to our third question. Why we classify ontological units (and such abstract categories as concepts or feelings) has evidently a basic "epistemological" purpose - no human being, no animal or any life form for that matter, could live without "knowing" the world, and could know the world without recognizing the similarities and differences in sensation and making the related abstractions and forming categories as regards the very complex environment in which it finds itself as a rule. Thanks to our "classificatory behaviour," we distinguish between what is useful, harmful or harmless; between what is interesting, relevant or trivial and irrelevant; what is good from what is bad.

In rather strict ontological terms, we try to classify what is "exterior", "observable", that which exists, as units of study as well as in principle, independently from the observer or classifier. And this is so, to be sure, for theoretical units of study and those empirical entities, processes and so on, "observable" through instrumental aid, as well as for macroscopic existents of ontology.

From a more dynamic point of view, we could consider the matter of **ontological classification in terms of individuals or particulars, and of universals;** the first category could then be discussed from a "material" and a "phenomenal" viewpoint, and the second one further from the perspective of extensionality and intensionality (properties, attributes...) (Grünberg, 1991). However, as I do not intend to discuss the matter from a technically logico-philosophical standpoint, and given the rather limited space hereafter in this final chapter, I shall briefly treat certain relevant points which are important epistemologically as well as from an ontological point of view.

Among the significant relevant points discussed earlier, one could perhaps find **an empirico-logical relationship between supervenience** (section 2.4.14) **and emergence** (section 2.1.5 and elsewhere, chapters 3.2 and 3.3), and this could possibly help us see **reduction**, or rather perhaps **antireduction, in a different light** (for a recent analysis of these concepts, see Kim, 1990). Supervenient qualities may also be seen, possibly, as the very general products of new subsets of ontological units emerging in the course of the evolutionary flow in the form of novel entities, properties... Their subvenient bases, as the already existent phenomena, would then be logically conceived as the producers of or rather the contributors to their production, which is actually a multi-determinant phenomenon. And this will possibly not be counter intuitive to our normal determinative expectancies, particularly in our daily, weekly, yearly lives as individuals, groups of individuals or communities and societies, because the contingency of the future not infrequently brings in its wake "emergencies" in the form of unexpected happenings or surprises, or undeterminable degrees of qualitatively expected happenings. Understandably, we might call this, if we should at all, (singular if not necessarily unique) **"event emergency"**, which can be contrasted with (generally occuring) **"phenomenon or regularity emergency"** of the evolutionary flow.

In this context, one might perhaps mention the term **"superimposition"**, borrowing its adjectival form "superimposed" from its use in embryology to qualify the progressive stages in which the fertilized egg, beginning with a limited amount of specificity, develops into more detail; this is identical with a principle already well established in biology - epigenesis (Commoner, 1971) (which should better be thought of in separation from its historically philosophical connotations). Whether we call the related relationship "supervenience" or "superimposition" in an evolutionarily biological context, there seems to exist what we may name a determinative gap in the appearance of emergent qualities (and entities...), and the distinction between resultant and emergent properties (and entities...) (see end of section 2.4.10) appears to be promisingly useful to further develop the idea. As a direct challenge to strict micro-determinism (hence, reductionism), R. L. Klee coins the term macro-determination to express what certain other writers have seen as the "editing" effect which is downward in direction and which makes the higher-level properties emergent in respect to what they edit (Klee, 1984). In this context, M. Polanyi's "hierarchy of boundary conditions" and H. Gutman's views on structuring in connection with the relationship between structure and function (section 2.4.3) could be referred to again.

In the matter of **the relationship of reductive operation to its ontology, or its universe of discourse in ontological terms** if you like, so many important points could certainly be mentioned and discussed. Interestingly and very basicly, this could also be seen as an issue of correspondence between the empirical world and our related epistemology, and evidently concerns the very essential philosophical question of truth and the differing "theories" about it - correspondence or reference, not to mention coherence in our quest of reduction as a relation. What I am planning to discuss briefly in the rest of this chapter is certain other basic issues implied by reduction in biology, and which are apparently of general philosophical interest as well.

Particularly in the final chapters of Part two, I have frequently stressed **the semantical or empirico-semantical aspect of our use of the term "reduction"**; just as the terms at both ends of the reduction as an ontological relationship, that is, those terms expressing the parts of the relata between the reducing and the reduced theories, laws, fields... ("segment of DNA" and, or located in, the "gene"; see Nagel, 1979, p. 283), this aspect should be critically discussed and clarified, both in general or during a given application of the reductive operation. **As the terms expressing the relata cannot be "transferred" or are not "transferable" from one level of explanation to the other, evidently due to semantical barriers, the clarification of the related or relatable terms can only be realized, in full, in their reciprocity.** And the presumably more or less widespread claim that we begin our epistemological construction or reconstruction of the world from the micro realm of atoms and subatomic particles seems to me to be very much connected with our general physicalist-reductionist approach to empirical reality at the philosophical level. As I can see it, when we seemingly "begin" this epistemological reconstruction, and even if we are scientists, we have already come a long way starting our quest of understanding and explaining the world from its macroscopic features. In fact, **the scientific** (if not necessarily the philosophical) **reason of our interest in the micro world of atoms to electrons to solitons in one direction, and atoms, molecules, macromolecules, viruses, and so on in the other, evidently lies in our curiosity and "conscious" endeavour to explain the macro world as we observe it more or less directly or in an unaided way.** And is this not in conformity with the basic reductionist attitude in philosophy - that is, to epistemologically base the observable world of entities, relations, and so on, on their counterparts at lower levels?

The rich diversity of the world, claimed to be only apparent by the (typical or strict) reductionist, in conjunction with the assumption that no real qualitative difference exists between the levels of being (Henle, 1985), can be accounted for by means of a recognition of the qualitative differentiae brought about by the organization of empirical levels. And given the complex relationality in the empirical world, "observed" also at the level of solitons as elementary particles in physics (Pak, 1986), the apparently more or less entrenched philosophical distinction between the non-relational, "intrinsic" characters of entities and their relational properties (Richardson, 1979) does not seem to be well or justifiably established. This, too, is likely a point of significance, at first sight at least, against a strict account of reduction; because supposedly distinct entities, such as the "atoms" of the ancient philosophy-science, seems to be rather unlikely to "locate" empirically and to satisfyingly express in an ultimate semantical manner. Particularly in the case of one-one, many-one, one-many correspondence, and similar causal-type relations between ontological levels, reduction in a strict sense is apparently not a feasible operation, and supervenience (representing a many-many relationship? and) as a more tolerant form of (partial) explanation is expectedly much more suited for theoretical as well as practical purposes.

Reduction has also been regarded as a certain type of progress in science; because scientific progress, apart from an increase in factual knowledge, is an improvement in the body of theories, particularly in the case of replacement of an accepted theory by a new theory (Kemeny and Oppenheim, 1970). In Nagel's view, on the other hand, and as he expresses when he considers the nonformal conditions for reduction in his "classical" work on science, his two well-known formal conditions for reduction do not suffice to distinguish trivial from noteworthy scientific achievements (Nagel, 1961; p. 358). In more comprehensive philosophical terms, scientific discoveries, however important they may be, do not in themselves "solve" philosophical problems (Grene, 1974c); which is not surprising at all, because philosophy and science are distinct though rather closely related activities, and expectedly either of them cannot possibly help the solution of the other's problems in a direct way. The common points between philosophy and biology (Lilly, 1962), for instance, lie in their borderland.

Like biology (see Efron, 1977) or another branch of science, and in reality in the case of any serious human activity, what we do must certainly be performed in a conscious manner, with its possible consequences to be seen in time. And in the case of reduction as a very significant epistemological operation in the philosophy of science (and in philosophy generally) such a consciousness may lead us away, for instance, from the dangers of an undue belief in the power of our symbolic systems. This power is such that full theoretical characterization of scientific possibility in any manner that would licence the inference from determination to reduction is not to be expected (Hellman and Thompson, 1975). For that matter, the power of any activity or its operational tools is inevitably limited.

In like manner, we must bear in mind that an undue emphasis on quantity with a disregard of qualitative aspects of phenomena would also lead us to an unnecessary reductionist attitude. The limits of an unduely quantitative approach to the empirical world are to be clearly seen in tha case of biological systems; because, ontologically speaking, the mathematically expressed values of different levels of organization, in human biochemistry, for instance, show us that there can be no mathematical demarcation line of values, but always upper or maximal and lower or minimal levels of a quantity as it is related to a given quality. The human blood values for most if not every component of it reveal significant ranges changing from community to community, from individual to individual, from time to time in the same individual; and, realistically speaking, a more or less strict reductive relation between these values and those of their corresponding and qualitatively different level of clinical findings would obviously not be expected.

In short, neither strict logic nor strict mathematics without the sufficient consideration of the empirically qualitative aspects would help us much as tools of approach and operation in our reductive endeavour in philosophy. Every empirical level must be studied from the point of view of its own organizational features so that a tolerant degree of reduction can be secured in in the philosophy of biology, and of science in general.

CONCLUSION : A SYNTHESIS, "FINAL" AND "NONFINAL"

By Way of "Introduction"

In principle, I think, a dissertation or a similar academic work in philosophy would end, following the "discussion" chapter, with two sorts of implications: those of general philosophical interest, and a conclusion rather concerning the more or less direct results that can be drawn from the subject matter of the work. I have discussed the former in the preceding part. The latter I am going to treat in the present context, with a reconsideration of the general implications later on.

The topic of reduction in life sciences has become an interesting philosophical problem for me apparently for at least two reasons - because of my medical background and my psychological makeup. The second one, as an external factor, appears to be the less important of the two, for the approach to any major philosophical issue is understandably under the impact of certain psychological determinants. And there evidently exist people in life sciences with a wide variety of conceptions as regards the issue of reduction, although they may not be aware of it as a point of philosophical or general scientific interest; this would evidently be "observable" in their scientific activity, in their theorizing, research, interpretation, and application. Other things being equal, it seems, the range of this variety among the basic life scientists and health professionals is possibly not less great than it is within philosophical circles.

Apart from such implications which do have significant effects on scientific activity (on biology and psychology, for instance) and its practical applications (such as clinical work), the problem of reduction has appeared to me as a general philosophical topic of great interest and with very rich ramifications within philosophical activity as a whole. The more interested one is, the more so. And I intend, in this concluding part of my dissertation, to share this interest with my readers, hoping that I shall have enhanced their interest in this overall philosophical problem that seems to pervade the activity, possibly in almost all of its major aspects.

Problems of Reduction in Philosophy

Although several problems in philosophy have been called "reduction", it may not be readily realizable to point out their common denominator. This, however, seems to be understandable, for, as must generally be the case in other activities as well, the "coiners" and "borrowers" of terms in philosophy may not necessarily be so keen or meticulous and methodical in their "creation" and/or re-use of those terms - a first, perhaps intuitive semantical approximation seem to suffice for many if not all "philosophical" purposes. A conceptually or logico-semantically sophisticated analysis seems to follow rather than precede terminology, obviously due to the need to work on an already existing professional linguistic construct. Generally speaking, an etymological-semantical consistency is apparently not a matter of professional concern in philosophy. This may perhaps be seen as a "belated" critical attitude on the part of the philosopher, supposedly and "ideally" a "critically" thinking person.

In actual professional practice, however, **the basicly if not purely semantical content** appears, from a functional point of view, to be **much more important than the etymological-semantical load**, and the situation would certainly not be different in the case of the problem of reduction. If we leave aside the use of the term "reduction" in an ontological sense in sciences, that "the living systems are composed of atoms" in connection with reduction in biology for instance, in my view basicly a matter of historical concern, with no appreciable philosophical implications today, **our problem is an epistemological one**. And as what I understand from "philosophical activity" is, in its core, a critical semantical endeavour directed to a conceptual clarification of our conceptual network in any given domain, the epistemology or rather the epistemological problem I intend to consider has been approached by an analysis of what we understand (**and what we have to understand**) by the term "reduction".

From an etymological viewpoint, all the same and in our context, "reduction" is "to diminish to a smaller number, amount, extent, in size or value, and so on, or to a single thing"; and, also, "to lower, diminish, lessen"; further, "to bring under rules or within certain limits of description". **In philosophical, more specifically epistemological terms,** what would matter appears to be **a conceptual-semantical economy** as regards a certain section of the ontology of the world. However "small" it may be, this section must certainly be "complex" so far as philosophical reduction is concerned, for it is a **relationship, a matter of ontological distance between at least two organizational units and/or, dynamically speaking, two processes at different but related levels of organization**. We must consider, additionally, what could generally be termed **the mechanism** connecting the two levels, and which would help us explain the upper-level states of affairs in terms of the lower-level ones.

It must rather be clear from the ongoing account, quite brief as it may be, that the philosopher's concern over reduction is **"to philosophically found"** the conceptual framework of general phenomena of philosophical interest, such as those of life systems or the psychological sphere, **on as little theoretical elements or components as possible which are supposedly more "essential"**. From the standpoint of the philosophy of science, the latter are said to constitute **the reducing theory** and the former **the reduced theory**. Thus, upper-level phenomena are admittedly expressed, **or rather explained, in terms of** those of lower-level ones.

Theory reduction in (the philosophy of) science is known to be typically represented, methodologically as well as from a historical viewpoint, by "the classical account" or "the received view" formulated by E. Nagel whereby two epistemological operations are to be realized. One of the conditions upon which these operations are based is known as **the condition of connectibility**, according to which all the terms (concepts) of the reduced (or rather reducible) or high-level theory should be systematically connected with some of the terms (concepts) of the reducing or low-level theory either by synthetic statements, explicit definitions or some other semantic relation. In the case of **the condition of derivability**, each law of the reducible theory should be deducible from the reducing theory, together with the statements that connect the higher-level concepts with the lower-level ones, and with a description of relevant boundary conditions in the vocabulary of the reduced theory.

This rather schematic view of theory reduction, though it has apparently become a guiding formulation or framework in the philosophy of science, has been found to be rather strict to work on, and new approaches and insights have been developed for a much better clarification of the higher- and lower-level theories, hence their corresponding ontologies. The attempts to explain or clarify the **part-whole relationship** (of structures or systems); **intra- and inter-level (or micro-) reductions; interfield theories;** and **type-type and token-token reductions,** and other improvements in the area of reductive operations in sciences, may be mentioned here, most of which rather directly concern our main theme in this work, namely reduction in biology.

But before considering the latter topic, we should mention, however briefly, other types of reduction in philosophy. One of them concerns the philosophy of science in general, that is **that of the theoretical to observable entities**. An essentially different set is found in the philosophy of the formal disciplines, where **the reduction of syllogistic theory to (monadic) logic** or **Russell's axiom of reducibility** are among the examples to be given in logic, while **the**

Kuratowski reduction of the natural numbers to sets ultimately containing the null set is possibly the most representative one in mathematics.

It must be rather clear, I think, that in **the application of the principle of conceptual economy** (or **Occam's razor** as has traditionally been known) in all these instances in different areas of philososphy, the general reductive approach can be truely operational, fruitful and explanatory, hence philosophically or epistemologically functional, only if **the subject matter concerning the related field(s) in its basic outline** is known and conceived well, a point apparently neglected by not a few philosophers in widely differing areas such as the philosophy of biology, that of psychology or, on the other end perhaps, ethics.

Reduction in Biology

Before considering directly the theme of this section, and following that of the previous one, it might perhaps be permissible to direct our attention, in however a brief fashion, to a certain general point in the matter of reduction which, in my view, is generally overlooked. It may not be an inevitable consideration, for certain readers at least, but my devotion of a whole though short chapter to it (Chapter 1.4), has apparently given me the right, at this stage of the dissertation, of presenting it in a summary form.

So far as I have been able to observe, the general concepts of 'matter' and 'the physical' are not defined, in general dictionaries, as differently as it should be, and particularly insofar as it concerns a philosophical treatment of them. The common semantical core is constituted by "having the properties of occupying space and being known to us by our senses." Matter being defined as "that of which the whole sensible world is composed", the adjectives "material" and "physical" both signify the quality of pertaining to or connected with nature, matter, or material nature, as opposed to being mental or moral.

What is physical appears to be related to the world of our senses, thus directly to the (humanly) macroscopic world, and indirectly to its "microscopic" realm. **Matter**, ontologically speaking and in the sense used in our context, obviously covers the whole empirical range of existence **at its lowest level**, thus exhausting the possibilities of ontology for any entity (and property, relation... as the case may be). Besides the common property of **spatiotemporal existence or space-time occupancy**, and being similar but not identical concepts, matter can be said to represent the lowest level of organization in the empirical world, forming one of the basic units in physics; while what is physical is represented by just by whatever exists spatiotemporally irrespective of whether it belongs to a simple or complex level of organization, thus comprising the whole gamut of **the empirically possible organizational manifestations of matter** (at least so far in the process of evolution).

One central implication of the above consideration, and of the distinction between "matter" and "the physical" in our context, is that both ontologically and conceptually the former constitutes the subject matter of physics in the realm of sciences whereas the latter, seen in the possibly most general sense, makes up all the topics of all the sciences, from mechanics and subatomic physics to sociology and human psychology. Viewed thus, the etymological relationship between the terms "physics" and "physical" becomes insignifant, not to be taken into account for it may be confusing in a philosophical context such as ours. And this appears to be the crucial point just before we begin our epistemological analysis of what is meant by "reduction in biology", for **semantics must certainly not be subdued to etymology.** To sum up in one sentence, while **matter is essentially or primarily a concept of** (the science of) **physics, what is physical may concern any scientific field.** This distinction has other important implications as mentioned in the related chapter of the work, but the one related to our present considerations must be rather obvious - biological or life systems, as units of empirical existence, are certainly physical structures; it would not follow from this, however, that they are physically explainable in the sense that they are, epistemologically speaking, capable of being exhaustively or almost exhaustively accounted for within the domain of physics, that is through physical theories and laws.

A similar consideration seems to be relevant as regards **the applicability of mathematical formulations and operations** to the study of life systems. The more definite and clearer mathematical expressibility in the case of structures and processes that make up the subject matter of physics, possibly in comparison with biological sciences, should not in any way suggest that the latter would thus have "a lower scientific status" in any significant sense of the term. Mathematicity, hence mathematical expressibility, in the form of countability, measurability and calculability, appears to be a ubiqutous property of the world, whatever the related level of organization and in whatever quality and to what extent the application of mathematics might be realized in different areas of science.

Of the two considerations above, oriented to near a priori **reductive operations as regards life sciences**, the first has been oriented to what may be called **a direct physicalist stance**, and the second to what could be seen as **an indirect one**. In any case, such primarily philosophical or, perhaps, "metaphysical" approaches to reducibility appear to be unfounded or unjustified, for reduction as an operation must begin at the level of an activity and within the limits of its philosophy, for otherwise, and although a definitonal generality may have been reached earlier, it would be like an "accomplished fact" or rather "accomplished operation" in philosophy which would remain unaccounted.

The attempts to reduce biological theories and laws to their physical counterparts in the light of the classical account of theory reduction have yielded complicated pictures, apparently due to the very complex nature of life systems, their functioning and ongoing processes. Very roughly speaking, this should only be expected, evidently because the distance to be covered in the reductive operation is too great to be rendered to an overall simplification. **The concept of the levels of organization** has thus been of great theoretical and operational value, if not always directly, in the appreciation of the difficulties inherent in biological reduction.

The relation between the "two genetics", for instance, and as the most typical example of reduction in life sciences perhaps, have apparently given rise to enormous difficulties as the philosophers of science interested in biology learned more and more about the nature of heredity and genetical phenomena. This seemingly paradoxical situation, quite in compliance with the observation just expressed above on the very complex nature of biological reduction, have urged the philosopher to be on his or her guard against undue oversimplification in an attempt to give a "physical" (that is, "as related to physics") account of life processes. The formulation of type-type reductions, in strong, weak, or limited forms, namely one-one, many-one, or type derivability relations respectively, between the two sciences, or rather two theories in the present context, have so far not been quite applicable successfully in the case of reduction in genetics because such concepts as genes, chromosomes, and so on, terms of the Mendelian genetics, cannot be redefined by means of biochemical terms as neat explicit expressions of relations at the molecular level.

All such considerations certainly need a critical semantical treatment and clarification, for evidently **reduction as an explanatory operation implies itself the necessity of a semantical concern of what we mean by it.** And I hope that in the next section I shall have summarized the issue critically from a logical-semantical point of view, in philosophy generally as well as in the philosophy of biology.

In general empirical terms, and apart from axiomatic and/or formalistic considerations (in theory reduction), the relationship between the corresponding phenomena at different levels of organization should rather be based, apparently, on ontological grounds even if our concern is primarily an epistemological one. Intuitively or at first glance, at least, such a relationship would be conceived in the light of causal connection(s), taking into account the temporal dimension as well. "Epiphenomenon" must be a familiar term, particularly in the history of philosophy and so far as the so-called mind-brain relation is concerned, and "parallelism" has also been used to desribe similar relationships. Among other terms, "correspondence" deserves, in my view, to be a favourite one, and a candidate of choice for our discussion on the organizational levels and theory reduction in biology.

In the realm of biology, **correspondence** (or **correlation**) seems to be a **necessary empirical condition**, for instance in the relationship between a structural unit (such as a cell, part or organ) and its related function. In all the significant biological phenomena in higher forms of life, such as fecundation, digestion, growth, perception and so on, what occurs is known to be very highly complex with the involvement of enzymatic activity at the biomolecular level. The complexity is enhanced not only by the sheer complexity of the structure, and of the function at a given moment, but by the additional and complex feedback mechanisms of circular control, with highly complex reciprocity relationships between the levels involved. Thus, for an overall activity such as moving one's arm during a physical exercise of some duration for instance, the neural, muscular, vascular phenomena with their related correspondent cellular, biochemical... counterparts are so integrated as to form an apparent functional whole at the biological level, but with multitudinous reciprocal lower-level phenomena seen from an analytical-empirical point of view.

Evidently, I think, what we might call "classical causality" as a basicly simple empirical connection would fail for any comprehensive account of interlevel relationship as regards biological phenomena, and this for at least three reasons - first, because it would not take into account the multidirectional temporality, that is a back-and-forth empirical flow accompanying the interrelated phenomena; secondly, and parallel to the first point, it could not scientifically account for the circularity and reciprocity itself, that is the directly empirical aspect of the states of affairs;
and thirdly, as the crucial point in the matter of reduction, the interlevel relationship which is expected to be accounted for, above all thanks to intertheoretic relations, cannot possibly be explained in terms of a causal connection, however comprehensively it may be conceived and not just as cause-effect relationship.

If science is about phenomena of the world, using the term in a very general sense denoting regularly occuring states of affairs, then **scientific explanation** could be defined very briefly as **accounts of these phenomena in terms of regular connections between two or more sets of them in a space-time setting.** The latter term would mean, in our present context, the empirical conditions, including the initial and also theoreticly formulated ontology, and a before-and-after ordering. The epistemological counterpart of a phenomenon as an ontological unit is a scientific generalization concerning a certain kind of occurence at a certain level of organization and formulated within the framework set by one or more theories.

Not infrequently perhaps, and **in particular in life sciences** and their differentiated or metamorphized extensions such as psychology or sociology, **the explanation is a causal one,** that is to say it takes **the form of a regular relation between two** (or more) **phenomena.** In other words, it is an attempt to give an answer to **the question "why?"** (in a non-teleological sense) as regards the world of phenomena. As for the "how?" question, it implies an extended link, an overall account to be given to fill the empirical or space-time gap between the related phenomena, usually and simply termed "**the cause-effect relationship**". Due to the highly complex quality of this relationship as a rule in the case of life phenomena, the scientific answer to the "how?" question is given in the form of what is generally called **a mechanism**.

The distinction between the universal and statistical laws or generalizations, as it is frequently made in the philosophy of science, need not concern us here, at least not necessarily. One might perhaps say that at the end of the whole discussion in the present work, particularly in Part 2, certain implications could actually be drawn, however couvert they may be, regarding the matter; particularly because it concerns the question whether biology has a respectable scientific status as its generalizations are as a rule not of a universal nature, a conclusion drawn from a comparison with the "physical sciences".

The so-called strong deductive formulations being apparently inapplicable in the case of life sciences, and **the weak inductive-probabilistic generalizations insufficiently simple in or for the explanation of interlevel relationships as regards biological phenomena**, another concept has been developed, or rather borrowed from elsewhere and applied in this context, which would supposedly account for this relationship. This is what has been called **supervenience**, an explanatory idea that was originally used to give an account of the relationship between our moral values (as the explananda) and the empirical world of phenomena (as the explanans). It represents, significantly, **a determinative relationship in that one characteristic is said to be supervenient upon others if, although it does not follow deductively from them, it cannot vary unless they do.** In the case of psychological phenomena, for instance, any given mental state is likely to have its "multiple physical realizations", in the usual philosophical terminology, specific to the physical structures or the biological species; perhaps more pertinently from a scientific-philosophical point of view, mental phenomena could be said to be supervenient upon corresponding neurobiological ones if the former will vary only in case the latter do so as well, and not otherwise.

The implications of this in the matter of reduction in general as frequently considered in the literature, and its relevance to the topic of biological reduction must be rather obvious. **Biological phenomena can be said to have a supervenience relationship to (scientifically) "physical" phenomena**, via organ, tissue, cellular, subcellular, biomolecular, chemical levels. And in general, on a possibly extended view of supervenience, any phenomenon (or a set of phenomena) at a certain level of organization would be said to be supervenient upon certain others at lower levels, so far as living systems are concerned as well as in general. In the case of genetics, as our specific area of interest in the present work, the most relevant application of the concept will evidently take place with a view **to accounting for the reductive relationship between the Mendelian and the molecular theories. Supervenience, in one of its different (weak, strong, or global) forms, appears to be relevantly applicable in the domain of genetics in connection with reduction.**

By Way of "Conclusion"

Because of its general philosophical value, I have planned to mention what we might call **the main implication of the work** in this last section of the Conclusion and not in the previous one on biological phenomena, although it has been treated in the second Part of the main text which is on reduction in life sciences. **As an epistemological operation between two interrelatable scientific theories, laws and/or fields with the view of giving an account of higher-level occurences by means of interrelated (and supposedly more basic) lower-level ones, reduction appears to represent a conceptually and semantically open-ended question;** this, in turn, seems to depend on an interpretative evaluation of the reductive relationship, for, evidently as in the case of most philosophical problems, the conceptual operations at hand are apparently dependent upon the basic "personal" methodological approach of the philosopher with highly differing semantical implications (which should not be taken, certainly, as implying arbitrariness or relativism). **The crucial conceptual-semantical point appears to be**, in my own philosophical interpretation of the problem of reduction, **the inevitable necessity of the preservation of the terms of the higher level theories, laws and fields because otherwise the reductive operation would be "meaningless" in any significant sense of the term.**

In the light of such a critical semantical interpretation, then, **reduction as an epistemological operation in the philosophy of science would serve as a partial explanation,** the term "partial" implying in this context a qualitative rather than quantitative characteristic. Further, and as an apparently related eesential point, **reductive operation would, and must, be seen as a necessary but not sufficient condition in our philosophical understanding of the relationship between theories, laws and fields as regards different levels of ontological organization. The ensuing operative-conceptual gap would be filled by the sufficient condition of philosophical completeness of the issue of reduction by an emphasis on the semantical content of the terms of the higher-level theories, laws and fields.**

Among other "general" implications of the material considered in the work are found those on **the relation of reduction to such philosophical concepts as causality and determinism,** (the theory and idea of) **evolution, differentiation** (as an essentially biological concept) and **diversification** (as a concept of philosophical interest), **extension and emergence**; and **its relation to such issues of philosophical import as ontology and classification.** Other sorts of implications can possibly be added to the list.

One would wonder, in the light of the whole discussion above, if every major philosophical operation could not be seen as a reduction, as one of my co-advisers somewhat sceptically drew to my attention following a discussion. Well, in a sense, they might.

SUMMARY

The term "reduction" has been in use in philosophy for some time to qualify such different logico-semantical operations or formulations as the reduction of syllogistic theory to monadic logic, Russell's axiom of reducibility, reduction of theoretical to observable entities in the philosophy of science, theory reduction in and between sciences (intra- and inter-theoretic reductions), successional and interlevel reductions, type-type and token-token reductions, reduction of "heat to motion", reduction of "chemistry to physics", the so-called psychophysical reduction, and so on. As would be seen from the above examples, the scope of these operations differ greatly, from the formulation of a "local" relationship in a given science or formal discipline to a rather comprehensive connection between two scientific disciplines as "theoretical wholes", whether "adjacent" (chemistry and physics) or "distantly situated" (mental processes and molecular biology).

The points common to all such conceptual operations appear to be an attempt to give a simpler, sometimes much simpler, and **seemingly more basic semantical-epistemological account** of a comparatively more complex structure, whether the terms of a syllogism or sets of natural numbers, molecular phenomena or psycological processes, that is to say either in formal disciplines with their analytic propositions or sciences having synthetic propositions with empirical content. What would possibly come to mind in this context is **the principle of conceptual** (or logical or perhaps even epistemological) **economy, known as Occam's razor** - that we should "not multiply the entities beyond necessity" in the philosophical treatment of categories, because "it would be vain to do with more what can be done with less". In other words, we should not have a recourse to unnecessary epistemological entities to give an account of any "ontology" - an ontological unit or a collection of them, namely entities, properties, relations, processes and steady states.

So far as sciences are concerned, this is **an epistemological operation** in the sense that what has been produced as "knowledge" and/or that which has conceptually been formulated as a "theory" are critically analysed and reconstructed or reformulated at the logico-semantical level so as to arrive at a philosophical clarity. This clarity, in turn, would be expected to help the scientist, potentially or theoreticly at least, in his or her further activity in the related domain.

Insofar as it concerns scientific activity in general, **reductionism** as the acceptance of the possibility of a more or less complete reduction between sciences and/or their theories has brought in its wake its dialectical counterpart, namely **antireductionism**. The latter as a "doctrine" has apparently its different versions, or perhaps rather differing degrees of refusing or accepting the reductive operation. **Reduction**, after all, is **a formulation of a relationship** between two (or more) levels of theories and/or laws or law-like formulations as regards the world of phenomena, and no one, possibly no "antireductionist" of our time for that matter, would and could claim that there exists no real or "organic" connection between the related levels of ontology. The problem that faces the philosopher of science interested in the matter of reduction today does not seem to be whether there is or could be any relation between different levels of organization in nature, but rather how such relations could be formulated in an epistemologically meaningful and justifiable way, which would also have operational implications, preferably **in science as well as in philosophy**. Antireductionism of the present day, in my view, must have a balancing function between the conceptual formulations (that may lead to reductio ad absurdum) and the (potentially narrow-angled) implications of each special or specific scientific domain.

As for **reduction in biology or life sciences**, it can be said that it is, basicly, an epistemological operation or formulation as regards the living systems, whether as individuals,

communities, their activities and interactions, or their overall development in time, that is, their evolution. The question here is **to what extent** these systems, their properties, life histories, relations, and the related processes can be formulated in terms of those of lower-level, non-organic systems or structures and processes which are the subject matter of physics (and chemistry). Although I have used in this context terms that are of ontological connotation, what matters, in the conception of reduction as it is viewed here, is certainly their being the subject matter of scientific activity which the philosopher of science, or the "epistemologist" if you like, critically analyses at the conceptual-semantical level.

Viewed thus, reduction in life sciences, and all reductive operations in the philosophy of science in principle, become **partial explanations** in the sense that they are the expressions of or formulations on **the mechanism(s) of the higher-level phenomena in question.** The longer **the distance between the reduced and the reducing theories, sciences or their law-level generalizations**, the easier it becomes for us to conceive or appreciate **this distance as a mechanism**, to use the term in a rather **general** sense, as the sum total of phenomena connecting the two levels, as in the case of reduction between the mental and the physical, or that between biology and physics. Otherwise, and as would be seen in the relationship between heat and molecular motion, and <u>even</u> between chemistry and physics, it seems that it becomes rather a controversial interpretation so far as the problem of reduction is concerned. Obviously, "the distance" is first to be covered, in principle and to whatever degree at a given period of time, by scientific research and theorizing, to be followed by a conceptual and semantical treatment in philosophical inquiry; but as this order cannot strictly be followed, the latter must justifiably be expected to be a directive force for the scientist as well.

In the reduction of the biological to the physical, whether we take it as theory reduction or otherwise, **teleology or teleonomy**, that is the purposeful behaviour of living systems, need also be taken into account, among others such as complexity or development, as one of the core differentiae of this level of organization. In any case, and as should be done in any reductive operation according to the account presented in this work, what is **conceptually and semantically important** is that the reducible systems in ontological terms and/or the related theory epistemologically speaking are to be considered **in their own right**, or to be described **at their own level of organization or existence, by way of the terms specific to them**; in other words, they should be conceived, understood and interpreted **as they are**, and not only or predominantly in the light of their determinants or prehistory, whether their causes, subvenient qualities or developmental characteristics. A very crucial point, apparently stressed only by a small number of philosophers, is that the lower-level phenomena, so far as they concern the biological (or yet higher) levels, do not have any **"meaning" and functionally or operationally significant semantical content** unless they are related to their corresponding upper-level counterparts. Otherwise, philosophical inquiry as well as scientific activity, as would be suggested within the context of reductive operations, would seem to be directed to an almost aimless or vain endeavour. And no scientist or philosopher so far seems to have succeeded in dispensing with the upper-lever biological terms, hence concepts, in their attempt to give a full reductive account of the reduced or reducible system or theory. Thus, no reduction in an exhaustive epistemological sense appear to be feasible or realizable.

To make the picture complete, then, the partial explanation realized by the search of the connecting links between the lower, physical phenomena and the upper, biological-level phenomena, we must additionally take into account, unavoidably it seems, a possibly full description or picture of the latter. We would thus have **a full epistemological account of life systems** with their characteristics, relations and so on, given, of course, the stage of the development of life sciences and the disciplines "auxiliary" to them (such as physics) at the time. We would then have **a full (though certainly tentative) explanation of life phenomena.**

Among what we might call the general philosophical implications of the above account on reduction in life sciences, what seem to me to be of interest are the principles of causality and determinism; evolution; differentiation or diversification, extension and emergence; and certain ontological problems of classification in relation to the concept of reduction.

In conclusion, it seems that we must see **the semantical open-ended characteristic of the reductive operation in the philosophy of biology, and of science generally**, because the problem of reduction appears to be one of interpretation (as a "philosophical necessity"), a way of seeing and conceiving the intra- and interlevel relationship in sciences.

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