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Interdisciplinary Thought

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Abstract: This essay examines types of overlapping thought between subjects. The definition of "interdisciplinarity" that is proposed is a thought process that overlaps subjects. It is oriented toward a topic as a whole, leading to standardization of the comprehension of phenomena by connecting partial explanations of different sciences with one another. The task of interdisciplinary research is not to be solved with a global interdisciplinary theory. It must be pursued within individual sciences in daily usage, and must entail attention to problems of language and clarifying the core questions. Theory should nurture practice, effecting a gradual change that promotes attention to questions that border on individuals' areas of specialization.

THIS ESSAY IS A SYNOPSIS of my dissertation which I completed at the end of 1989 in the subject of Philosophy at the University of Cologne. The idea for the thesis grew out of my studies in the subjects of biology and philosophy, and was ultimately germinated by the need to answer pressing (in the broadest sense anthropological) questions, which have emerged and remained unanswered both in the natural sciences as well as in the humanities.

Given this background a paper developed, which deals with different examples of overlapping thought between subjects. The goal was to discover as many forms of cooperation as possible and to systemize them. The primary focus was directed at the relation between the humanities and natural sciences, because it is here where the most interesting problems as well as the greatest difficulties lie for creating a bridge. Because I was concerned with generally promoting the exchange between different disciplines, I use the term "interdisciplinarity" as broadly as possible, and I will propose a definition that includes all possible forms of collaboration between the sciences.

The ever-increasing criticism against specialization is mainly attributed to the fear that we cannot, through specialization alone, master the pressing problems of modern mankind, such as the scarcity of nourishment or the destruction of the environment. These problems are much too complex to be judged appropriately, let alone be solved merely with the subject-knowledge of a single discipline or through a simple comparison of the details of knowledge from many disciplines. What is missing is an examination of the larger contexts, which are not apparent by stringing together our knowledge of individual details because this approach fails to comprehend the interactions between different factors. These interactions, however, often have an impact on the total behavior of a system and are usually subject to their own laws. A more comprehensive understanding of the phenomenon than currently exists will therefore have to be acquired if we hope to influence complex systems.

On the other hand, the necessity of a highly detailed analysis is undisputed if a topic is to be understood. Due to time limitations, it is already hardly possible given the extent of existing knowledge to be competent in even a single specialized discipline, let alone to be able to keep up with the developments in the neighboring sciences.

How is this dilemma to be solved?

In recent years the catchword "interdisciplinarity" has been set forth as an answer to this question. Interdisciplinarity is used as a collective term for subject-overlapping thought, i.e. for the characterization of every collaboration which bridges disciplines. One usually finds the term "interdisciplinarity" employed without specification as to what it is that is to be understood about it and an exact clarification of its meaning is seldom furnished with its utilization. It often appears that the term is used without awareness of the complexity of its meaning or the difficulties which are linked with the realization of the challenges of subject-overlapping research. Talk of "interdisciplinarity" occurs so often and in the most varied contexts that one can gain the impression that we are not dealing with a concrete concept, but rather with a catchword, which is connected with rather diffuse hopes for modification of the situation. Ultimately, it remains an open question as to if, and to what extent, a unity of science can be achieved within this essay.

It is therefore my opinion that it is necessary to undertake an exact systemization of interdisciplinary procedures. The potential and limitations of the various alternatives which should be known before beginning an interdisciplinary project will only become visible through the differentiation of application possibilities of this approach, which has until now remained very general. Only in this manner can the prospects of success be appraised realistically and the greatest possible benefit be gained.

This latter point is especially important, because many of these projects yield only marginally unsatisfactory results, or at best less than the desired .success. One learns almost exclusively about successful teamwork in the technical-scientific sphere. If no reasons for an unsuccessful coordination are identified and thus no fruitful exchange has been achieved, the danger exists that no further attempts will be undertaken. In part, this type of resignation has already been noted in reports about attempts at interdisciplinary problem solving. If this increase in "disillusionment" should prove to be premature, there might be reason for hope.

With the demand for interdisciplinarity, the question of overlapping unity among sciences is implicitly raised. This unity could provide a basis for all of the overlapping attempts to provide answers. The opinion which I advocate in this regard is the following:

Hopes should not be pinned to an approach which attempts with a *single* blow to establish unity among scientists on a meta-theoretical level, for example, the thesis that there is a method monism among all sciences or an ultimate unity of all scientific topics. Apart from the fact that meanwhile the sciences are too diverse and complex, such a theory would inevitably be much too general to provide concrete directives for the procedure of subject-overlapping research on a specific topic. But this is obviously what is missing. In addition, (and this is aimed at method monism) there is a firmly established tradition of separation between the so-called humanities and natural sciences. In these sciences it appears that totally different topics are being pursued, i.e. different subjects are dealt with which do not always lend themselves to the formation of any type of unifying scheme of scientific procedures. To my knowledge, these methods are not followed by scientists who occupy themselves with interdisciplinarity, just as little as other historic proposals for the creation of a unity amongst the scientists, such as those of Wilhelm von Humboldt, have been.

I am equally doubtful that subject-overlapping research can be facilitated through the development of a meta-language. Meta-language would be totally abstract, and it is unlikely that the aspects which a speciality science examines on a specific topic could be considered differentially enough and still maintain their specificity. This level of specificity is what is at stake however in the completion of any complex research inquiry into which the different scientific approaches shall be integrated. Besides, it is hardly conceivable that the scientists of all disciplines would be prepared to learn this meta-language, and if only for the previously mentioned reason of time constraints.

Rather, I would like to more precisely define "interdisciplinarity" or "interdisciplinary thought" as the attempt to connect the explanatory approaches of the different sciences with one another, with the goal of *explaining a specific phenomenon in its totality*, in other words with all the attributes that are ascribed to it. Under the word "phenomenon," I include all the conceivable research topics of the sciences, be they atoms, complete species in a biological sense, a philosophical theory, a historical epoch, or whatever else is viewed as deserving of research. As the leading thought for the pursuit of science, the goal of explaining phenomena, no matter the type, is presupposed. These should now be explained *in totality* during interdisciplinary research, and that means that the dividing line between them must be overcome, in as far as their different attributes fall under the "explanatory responsibilities" of different speciality disciplines. In other words, the chasms between the different lines of inquiry and their accompanying answers, should be overcome. One can describe this as an endeavor to establish unity of thought through the intermeshing of the questions of various lines of inquiry. Smooth transitions must be established between the subject-specific answers to these questions in such a manner that no gaps remain between them, which leave further questions concerning the relationships, i.e. the interactions between the different partial phenomena. In as far as a term does exist that expresses the supposition that something represents a unity in and of itself, the issue should be understood as a complex totality, whose individual aspects are analyzed by the respective disciplines which specialize in them. It is *the method of interaction of the individual pieces* which must be clarified in interdisciplinary questions: this method will not be analyzed by any discipline if the interacting components of a system do not fall into the responsibility sphere of that same discipline. The chasm existing here between the different levels of explanation is obviously that which is worth bridging in interdisciplinary research. The problem to be solved by a theory of interdisciplinarity is, in other words, that of how knowledge can be combined into a uniform picture.

The newness of this approach, in contrast to historic attempts, is that despite the uniformity of thought, variability in the scientific approach to problems remains perceived. In other words, the possibility of a flexible approach is associated with the idea of uniformity. In my opinion herein lies the importance of this paper: perhaps there is a new opportunity to create unity if one looks for smooth transitions between explanations by different areas of specialization. It must presently remain open whether the boundaries between sciences are completely dissolved through this transition. The unity would then lie not in a common foundation for all sciences, but in the subsequent overcoming of boundaries between individual sciences which aim at the research topic presenting the most diverse set of questions. This partial unity starting from the topic, from the bottom so to speak, consequently constitutes the difference from the previous attempts to create uniformity. Hope exists that the sciences can grow together into a whole through the production of vertical cross connections *by means of the topics*, and that the diversity of the research subjects will do justice despite the established relationships between them.

From this perspective of creating uniformity, the only aim in an interdisciplinary approach can be to point out the different possibilities of subject-overlapping thought, instead of looking for a directive to a fundamentally uniform means of approaching interdisciplinary research. The purpose of interdisciplinarity cannot be to overcome the abundance of specialization, specifically because the great variety of the research possibilities should be kept. No alternative to specialization is currently being explored; however a counterpole is, because the overview of the total object is in jeopardy of being lost with the advancing knowledge of details. It consequently does not make sense to overcome specialization, but rather to overcome a pursuit of science that stops at the fractionary method of looking at things necessary to specialized research.

Depending on the individual explanations to be connected, this requires very different cooperative attempts between the involved scientists, i.e. differing degrees of willingness to discuss the respective approaches foreign to the subject. For this reason alone it is my opinion that the task of interdisciplinary research is not to be solved with a global interdisciplinary theory.

Interdisciplinarity should also not be pursued primarily by theoreticians: rather it should find increasing acceptance within the individual sciences in daily usage. In other words, it should lead to a gradual change in position vis-a-vis the pursuit of science, to the extent that more attention is afforded the questions bordering one's own area of specialization. Only then can the accomplishments of "science a.s a whole" be integrated so that one's own individual position can be determined within it.

What is important at this point is the diversely expressed idea that the classification of phenomena, as perceived by humans and reflected in sciences, corresponds less to their nature, but instead is a more artificial classification (see for example Dirtfurth and Weizsäcker). These boundaries were possibly drawn only because our intellect cannot process the things any differently than as they are categorized in this artificial form. It is only due to this classification of cultivated specific conceptualization (i.e. developed different technical terminologies are responsible) that we now experience a problem relative to uniformity of the sciences. Perhaps this classification over time has let us forget that a complex topic is essentially constituted of the interaction between its individual pieces. For the most part, the present individual sciences perform research on specific aspects of phenomena and can therefore always only illustrate and comprehend partial processes. The existing interactions, however, refer to other partial aspects not taken into account. The problem of explanation in this interpretation therefore exists in understanding the respective dependencies between the partial aspects.

Consequently the individual sciences are to be understood as *purveyors of partial explanations in the need of complement*. To pursue interdisciplinary research, the method of interaction of the parts must be clarified. In this manner the dividing lines between the areas of specialty can be overcome, whereby the variability of the analytical approaches remains perceived.

In order to retain this perspective, the comprehension of phenomenon must be placed in the foreground, in other words, not the ability to formulate the research results into specific technical terminology, but to make rational comprehension accessible. By this, it is presupposed that it is possible to make one's own respective approaches intelligible to a scientist independent of his subject area, in so far as he is interested and is willing to enter in the explanation. Therefore, the "meta" language of interdisciplinarity would not be a formalizable language; rather it would "supersede" the technical terminology only in as far as it is not tied to a specific technical language and is comprehensible to every logically thinking person. So subject terms can be used without further problems, they must only be defined in an understandable language for all the scientists involved, and the same term cannot be given varying meanings, as is so often the case with different technical terminologies.

Hence, in interdisciplinary research, the connection of knowledge *elements* predominates, not the connection of whole sciences. Interdisciplinary research is therefore independent of the respective valid classification of the given sciences.

The interdisciplinary position described is in a certain sense comparable to that of a person trying to solve a puzzle: it is of no use to have only the individual pieces in your hand. If one wants to see the entire picture, one must put the pieces together, and for this purpose we must look at every single piece exactly, in terms of what is represented on it as well as its perimeters. The whole puzzle is only comprehensible after assembly when one views the picture from the overall perspective rather than examining the individual pieces, because as long as one perceives the boundaries clearly, they impede the viewer's ability to grasp the whole and thus the purpose of the enterprise is not achieved.

Because an interdisciplinary research effort as described orients itself on the respective individually important questions which transgress the boundaries of the speciality science, it has a predominantly pragmatic character. Also, because the cooperation between the sciences must therefore make use of different means as to the problem at hand, the development of a unified interdisciplinary theory cannot be stated as the desired goal. The prospect of being able to provide a valid general interdisciplinary methodology, which goes beyond very general recommendations, appears negligible to me. Therefore, I have attempted to undertake the classification of the numerous examples for clarification of the different possibilities of subject-overlapping collaboration, which can be viewed as approaches to interdisciplinary exchange which are already being practiced.

Before proceeding, let it be said that I do not want to emphasize that sciences be tied to another as a whole, thereby creating new "interdisciplines," as it is often stated (examples for such interdisciplines are biochemistry, paralegal sociology, psychoneuroimmunology, etc.). These are, of course, in each case proof for a successful and already established exchange, but they are only examples of extensive cooperation, and I would like to include every possibility for the direct reciprocal stimulation between the sciences even if no concrete results yet exist. The creation of a discipline is not really necessary if the priority in interdisciplinarity is a complete explanation of a phenomenon. It can be totally sufficient for the solution of a subject-overlapping problem only if the individual results or methods of one discipline are utilized by the other for its own research. In such a case, only partial spheres of different sciences would be integrated with one another, as it happens so often in interdisciplinary practice.

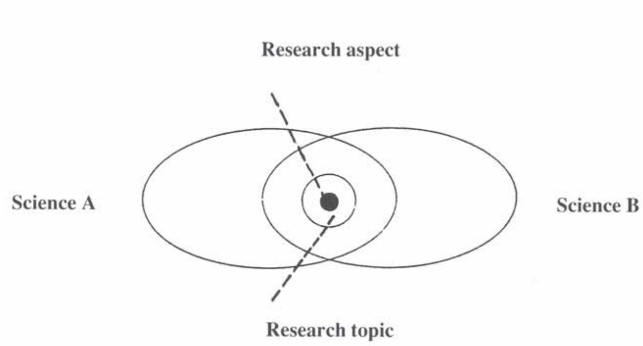
For the classification itself, I would like to differentiate between the already mentioned *total phenomenon, the research topic* and the *research, i.e. partial aspects*, independent of the type of interdisciplinary cooperation. Relative to one of these aspects, a common interest must exist in different sciences if there is to be a reason for interdisciplinary research. The individual object with all of its constituted characteristics, which appears to us as a uniform whole in the pre-scientific experience, is to be understood by the term *total phenomenon*. The term *research topic* refers to all partial phenomena which a specific science can analyze on this total phenomenon; and a single *aspect* on one such topic corresponds to a possible research perspective of the partial phenomena. In this manner, for example, one can analyze a specific behavior on the total phenomenon "human" (and thereby a partial phenomenon of this whole object) through neurophysiological, hormonal, psychological and sociological aspects, and although very different disciplines are involved in this case, come to the conclusion that it is a question of a specific unequivocally defined sickness, such as. for example, manic depressive behavior. Yet the individual "thrusts" can be triggered through specific outer influence and the course of the sickness can be dependant on numerous factors.

The term "research topic," therefore, usually coincides with the "total phenomenon" only from an interdisciplinary viewpoint; in individual sciences it may only rarely be the case. This differentiation between total phenomenon, research topic and aspect seems to be very important for an evaluation of the interdisciplinary cooperative possibilities, because these various possibilities should relate to the individual knowledge *elements* of the different sciences and not to the whole of science. The individual findings which are to he linked to one another, namely, have a more or less extensive claim to clarification in reference to the total phenomenon. Their need for complement is thereby connected to other sciences, as well as the decision as to what extent a certain question deals with an interdisciplinary problem.

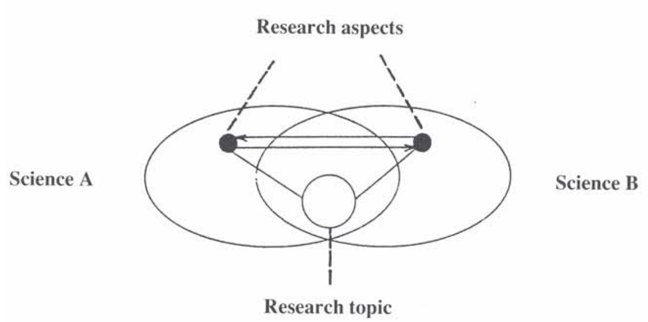
With regard to the individual distinctions of the various forms of teamwork. I agree with Vosskamp that there are different possibilities of classification and not only a succession of increasing degrees of interaction. In my opinion at least two dimensions must be taken into consideration for this classification, which I have termed as "levels" on the one hand and "criteria" on the other based on the pattern of Vosskamp.

Relative to the criteria noted above, I would first like to differentiate whether two (or more) disciplines which are involved in an interdisciplinary research project can only contribute their internally gained facts for the resolution of a problem separately because they analyze different partial phenomena, i.e. aspects of an object, or if they are able to recognize commonalties in the topics they analyzed by themselves. In the latter case, their *analysis topics* (and that which is characterized by the terms utilized in sciences) must be at least partially identical (see examples below). This means that the involved scientists must acquaint themselves with the mode of thinking of each of the different disciplines to a considerable degree. It is only when they really understand which questions this methodology is trying to answer that both (or more) of the research approaches can formulate a common concept for addressing overlapping questions. What is to be analyzed is to what extent the terms used in the different sciences, be they identical or not. represent the same thing. If the results of many sciences are integrated in this manner, I will use the term "*intermeshing*" to express the close interwovenness of the analyzed topics. Eventually, it is even possible that the disciplines will exchange their foundations and use them for continued research. If the analyzed topics, as well as the corresponding terms, can still be unequivocally kept apart even after the joint work, I will term this "*complementing*" to emphasize the possibility of a sharp demarcation. The term "intermeshing" should thus only be used when sciences intersect relative to the topics they analyze, whether inclusive of the analyzed partial aspect (=*analytic viewpoint*) or not. Therefore. I characterize the two criteria as follows:

1) *Intermeshing*: Agreement in respect to the analyzed topic.
a) The closest relationship probably exists between sciences in which the analysis *aspect* is in agreement, because they regard the same partial phenomenon from different viewpoints {from differing starting points). This conceptualization is also used when the same partial phenomenon is to be observed on different individual objects (total phenomenon), in other words, the same analysis topic exists in the different analysis objects, for example, the same chemical reaction in plants, animals and non-living systems. The clearest examples of this are probably provided by the interdisciplinary connections ("interdisciplines") of the natural sciences (including the technical sciences). In this way, biochemistry expresses the close bond between biology and chemistry. Biology focuses on the organism as a whole and in the analysis of the phenomena which constitute life, delves deeper into the detail of the structure, i.e. the meaning of the parts of the whole take precedence (the function of the elements for the whole system). Chemistry, on the other hand, focuses on the individual elements (which are the fundamental building blocks of all matter) and analyzes only their immediate interactions. As such, the analysis aspect for both is the same however, in as far as biology proceeds until it reaches these elements. Graphically it can be visualized in this manner:

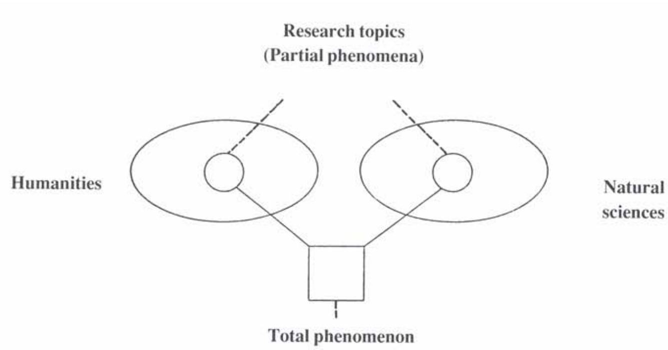


b) In the second place the connection between the sciences can be found because characteristics, which one assumes are in close correlation with one another, are being analyzed on the same total phenomenon. There exists here a conformity in respect to the analyzed *topic*, but not in respect to the analyzed *aspect*. The different aspects could be interpreted in such a manner that together they make up a partial phenomenon which is to be explained. An example of this is psychosomatic medicine. With such assumptions of immediate connections, it is frequently not exactly clear if the characteristics of the phenomenon in question have the same causes more or less independent of one another, making up one observable characteristic through interaction, or if the causes are themselves dependent on one another. It can also turn out that different effects are traceable to the same cause for which one previously postulated separate causes. In each case it should be clarified as to what one assumes based on the achieved level of analyses. Thus, it is possible that the analysis topics are identical, even if it was not previously assumed and one used different terms to describe them. What is decisive is that *no definite separation* can be undertaken between the observed aspects from the point of view of the phenomenon. The graphic illustration of this could look like this:



2) *Complementing*: Agreement in respect to the researched total phenomenon.

I have termed the less tightly connected form of interaction as complementary. I will use the term complementary when there is agreement that the analysis topics of different sciences belong to the *same total phenomenon*, but l*argely continue function independent of one another*. In other words, while the analyzed partial phenomena constitute a whole, one cannot assume that they are in close correlation to one another. Graphically this can be illustrated as follows:



Other *criteria* of interdisciplinary research which I have adopted from Vosskamp are problem-, concept- and method-interdisciplinarity.

In *problem-interdisciplinarity* one question predominates, of which from the beginning, it is unclear which sciences will be affected by it. Examples for problem-interdisciplinarity are communication and environmental research, as well as the utopian research undertaken by Vosskamp. In the course of the analysis, it is usually unclear at the onset which results will become of interest from which discipline, and thus remain open until the conclusion of the project. From this explanation it is probably clear as to what is meant and no further description is necessary for problem-interdisciplinarity.

The term *concept-interdisciplinarity* refers to a collaboration in which one science adopts a model from another, the latter of which has developed as a subject-specific problem, that is, it turns out that this model is applicable to a larger sphere than one had originally anticipated. Examples of concept-interdisciplinarity are provided by the so called structural sciences. In my dissertation. 1 have dealt with system theory, cybernetics, information theory, synergetics, game theory, semiotics, as well as structuralism in their own chapters respectively. The reason for this detailed representation is that what these sciences can achieve for an interdisciplinary approach can only be made clear through concrete examples. The agreement found here between research objects from the different disciplines has fascinated me. This agreement provides a reason for high expectations because it doesn't only analyze forma] analogies like the purely mathematical sciences do, but also uncovers further commonalties through the targeted search for additional contextual parallels stemming from these sciences. If one must be satisfied by the "purely" formal sciences of logic and mathematics relative to striving for standardization with the discovery of laws which can only be formally described, then in a narrow sense common methods of function are found in the structural sciences and through this, structural affinities are indicated. Since the reference to the concrete individual topics is immediate (even if the methods are formal), an opportunity is provided for the discovery of direct relationships between different objects which are able to utilize the same model. On the roundabout way of formal comparability, identical underlying (physical-chemical) mechanisms have been discovered by the structural sciences in several cases, and this means that substantially closer relations exist here than one first assumes. In order to substantiate this premise. I would also like to examine it in more detail.

What is at stake in the sciences is the manner of connection between the elements of dynamic systems in the broadest sense. The viable models presented here have proven themselves as decisive for their methodology. Their type of interconnectivity will, therefore, be analyzed independent of the type of elements themselves, even on a formal level. What is important is their functional coherence, which one mainly tries to grasp through mathematical means. The goal is the systemization of functional principles which might account for different systems. The term "functional equivalence" as used here means that certain parts of an intcrmeshing pattern can play *identical roles far the total system*, despite the difference in the elements that form them. If there are more direct relationships existing between the systems which can utilize the same model (for example, based on the agreement of the underlying chemical reaction, the similarity in the types of system building blocks or even their identity), then in a further step, additional analysts can occur in each case.

Since the structural sciences analyze which characteristics systems have based on the intermeshing design of their elements (i.e. due to the special type of interaction they produce) and not because of their existence as such, one can say that they attempt to grasp the phenomenon of "complexity." Because interdisciplinary research is often necessary due to the complexity of an analysis topic which cannot be mastered by one discipline, the structural sciences have special significance for subject-overlapping research.

If these sciences can work out the meaning of the connection between types of elements, a potential influence exists on the individual sciences in the following respect: in the explanation of phenomenon, these sciences are made aware of the fact that *the type of relationship between the individual pieces* should also to be taken into consideration. Some attributes develop only through their combination and therefore, they escape a purely analytical examination. In light of interdisciplinarity, the following notion can be derived: if new attributes *automatically* develop through the combination of certain already well-known and well-understood elements without some third item having to be added as a causal element, as representatives of these sciences would contend, then one should not demand that an additional theory is necessary beyond the present scientific explanation in order to further illustrate the correlation of the phenomenon in question, so that the existence of close interdisciplinary relationships between the relevant sciences is guaranteed. What is missing then, is the necessity to overcome a chasm or barrier between the different terms which we are forced to use to describe different levels of complexity. The bridge would already exist with proof of the immediate development of new attributes on an object through the combination of those already known, and there would be nothing additional to explain. The seamless bridging from one description to another, as demanded for interdisciplinary research, would thus already be achieved.

To begin with, *method-interdisciplinarity* is present between all disciplines which make use of the formal model of logic and mathematics. The commonalties however, do not exceed the purely abstract analogies as described for the structural sciences, so that the connecting effect usually remains very low. On the other hand, within a subject area like the natural sciences, the often observed commonalties of a large part of the methods express a high level of similarity between their work technique, i.e. the close relationship in how they approach a problem. The fact that many methods are simultaneously utilized is, at the same time, an indication that the analysis topics being dealt with are closely related to one another. In this way. for example, chemical-physical methods are often used in biology because their objects can be, to a large degree, described by them.

It must immediately be added, however, that although the assumption of methods between sciences is an indication that comparability of objects exists, it does not follow that one can therefore be reduced to the other. In this way, for example, biology cannot be reduced to physics and/or chemistry just because a large part of its analysis utilizes the methods of these sciences. Physical and chemical processes make up only partial aspects of living organisms: in other words, no total identifiability is provided. There are different levels of description for attributes of total phenomena. On every level there are different demands for explanation; i.e. different types of explanations are expected. On one hand, there are different degrees of integration which might explain the attributes of a system from the combination of its elements and on the other hand, there are different degrees of capabilities (at least with living organisms). This is what makes the utilization of a different vocabulary necessary; the problem, therefore, exists in creating bridges between the different terminological systems without succumbing to the danger of reductionism. At the beginning of such an "explanation hierarchy," a physical-chemical descriptive level can exist, as in the case of the explanation of a living organism's functioning. The language utilized here describes the behavior of the smallest building blocks of matter (i.e. a partial aspect of living organisms), and does not contain the terms which are utilized in the description of "behavior" in an ethological sense or offer recourse by explaining the motives of behavior. A physical description of process occurrences can, therefore, provide no satisfactory explanation for this "behavior"; very different *explicanda* exist here. Additional explanations for the correlations become necessary for each higher level of description, and on each level there can be an individual special discipline with its own particular terminology. This is why 'explanation' means something different on every level and why each level has its own catalog of questions! It is precisely these questions, which belong to the individual levels of description that are at stake, and it is important to keep them apart.

Naturally, several of the criteria mentioned can be applied to a certain research project, that is to say, no classification exists which allows for the strict segregation in light of individual interdisciplinary research plans. Moreover, what is at stake in the differentiation of criteria is reaching clarity in each case as to the extent of exchange between the sciences during a concrete project, and in which regard the exchange exists.

Beside these criteria, there are also different *degrees* of interdisciplinary cooperation, of which I differentiate the following:

1) The lowest level in regard to the attributes which connect subjects are constituted by logic and mathematics because they offer the most general forms of subject-bridging models at our disposal, namely those on a purely abstractual level (see above). The commonalties uncovered by them are described with abstract measures, which means that the comparable aspects are so restricted that one can only speak of an indirect connection. It is a question of synthesis on a purely theoretical level, i.e. on the level of the form and not of the topics themselves.

2) It is difficult to decide the placement of the aforementioned structural sciences in the succession of levels as their results feature very different and far-reaching connections between the individual disciplines. I would like to place them in between the purely formal sciences and subsequent levels because of their high participation in formal usage of scientific mechanisms, although in part they uncover intermeshing between disciplines which are distantly related.

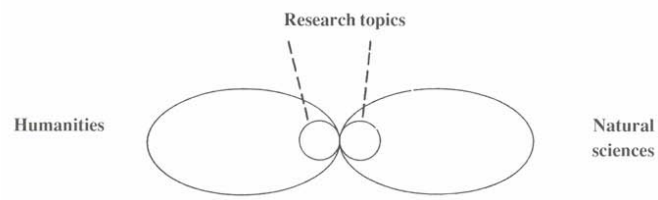
3) The next highest form of cooperation which I call *trandisciplinarity* denotes the connection between the humanities and natural sciences. What is at stake here, is the connection between disciplines which are classified into different spheres in the conventional scientific system; one which has been viewed for a long time neither as neighboring nor being in close relationship due to their topics. In the meantime, a rapprochement can be observed and the boundaries between these two spheres seem to have been partially overcome, although one cannot always speak of a fusion of the spheres. The fact that questions are even posed, which allow for the overstepping of these conventional boundaries between the spheres, can be expressed by the term "transdisciplinary thought."

As an example for transdisciplinary *complementing*. 1 have dealt with the epistemological problems of modern physics (theory of relativity, quantum theory and complementarity) in detail in my work, as well as the epistemological and anthropological problems of modern biology ("evolutionary epistemology" and ethology). Developmental psychology, gestalt psychology and the medical scienees are examples of transdisciplinary *intermeshing* between the humanities and the natural sciences, as is the much discussed (and very graphic) example of psychosomatic medicine in transdisciplinary research. "Both sides," i.e. most psychologists as well as most doctors, are in agreement that a close dependency exists between the phenomena they analyze, but the correlations arc clarified only in a few cases.

What takes place with such connections is less often a direct exchange of facts but more a reciprocal sensitization to the problem at hand. The many-sidedness of the problems at hand comes to light whenever a question, whose answer would overtax one or the other sphere, is approached from different starting points. This may cause the individual sciences to more strongly differentiate their explanation than they had previously done. It is also possible that the participating individual sciences become aware that their explanation does not cover the entire phenomenon through this process, but rather provides only a partial explanation. To fully understand a phenomenon, a reciprocal crossover of either purely natural scientific methods of observation or those of humanities is often necessary. The ability to change perspectives can therefore be stated as characteristic of transdisciplinary thought.

This is not to imply, however (as could possibly be concluded), that a connection between humanities and natural science approaches would have to lead to a uniform method of thought which might supersede the old. If, for example, as in the case of physics, the natural scientists recognize that their difficulties in the development of theories are of epistemological nature, one would hardly want to term physics as a hybrid form of humanities and the natural sciences. Rather, the development within a natural science has led to questioning in humanities, i.e. philosophical questioning, because the queries could no longer be answered purely by means of the natural sciences. If the physicists seek a new epistemological foundation for their discipline due to this, they do it explicitly in the consciousness of continuing to think philosophically; this, in turn, has influenced philosophy, which has received new input and has had to develop new procedures for the specification of its querying.

If such a close dependency exists without being able to call it intermeshing (because the querying from different disciplines refers directly to one another, but different terminology systems have to be used when dealing with them, as in the case of epistemological problems of modern physics). I will term the phenomenon as *connection points*. This term will denote that a direct relationship is nevertheless at hand. In the pattern of the previously shown graphics, such “connection points” can be illustrated in this way:



Transdisciplinarity places the highest demands on collaboration because one is dealing with widely disparate terminology systems and the communications are thus very difficult. One can therefore also characterize transdisciplinarity as “interdisciplinarity in the broadest sense.”

4) Transdisciplinarity is followed by *interdisciplinarity in the narrowest sense*, which I interpret as the collaboration between disciplines within the same scientific sphere, in other words, either as natural sciences or humanities. Biotechnology, hiomedical engineering or administrative sciences are examples of *complementing* here: examples of *intermeshing* are ecology, social biology, linguistics or neuroinformatics.

5) Aside from these “true” types of subject-overlapping cooperation, the problem of having to relate the individually acquired knowledge of the different parts of a very comprehensive discipline to one another can also arise. It can obviously not be taken for granted that all specialty areas of one discipline are in close relationship to one another. For examples in my work. I have again selected physics and biology, whose historical development 1 have more closely analyzed.

From the beginning, it is in no way clear how *hormonal* conditions influence the behavior of a living organism, even if no doubt exists as to the close connection between these living phenomena. The degree of difficulty in comprehending the reciprocal interactions between the different parts of a whole is especially apparent in such complex “whole phenomena” as living organisms. Evolutionary theory can be viewed as a thought which uniformly establishes biology as a discipline. Physics, on the other hand, primarily strives to find a uniform theoretical foundation for all of the individual forces analyzed in it; it is sometimes called the “world formula.” Its history can also be illustrated as an increasing standardization through the development of overlapping theories, i.e. theories that encompass more and more phenomena.

In both cases, a striving for a uniform method of viewing underlies the scientific efforts which can be seen as comparable to striving for unity within different sciences. I will, therefore, term the connection between individual sub-disciplines of a subject as “*interdisciplinarity in the smallest sense*.” It represents the closest form of collaboration in which possible contradictions can eventually and rather quickly come to light between two research approaches.

A scientific theoretical requirement of fundamental significance for interdisciplinary research is the following:

Because the exchange of results between sciences is what is at stake in interdisciplinarity, every interdisciplinary project should begin with a clarification of the questions for which a science is solely responsible, as well as a clarification of how the same analysis topics are approached by different sciences. In the first case there would then be no intersection, rather the participating sciences would complement each other; whereas in the agreement of the analysis topics it is a matter of interweaving between sciences (see above). The spheres for which only one science poses its special type of inquiry and has the appropriate method of response can thus be termed as purely subject-specific. Intersections do exist however, if the same questions (see above: analysis aspects) can be approached with differing methods.

Depending on the expanse of the analysis perspective, the different inquiries (approaches) of a discipline can encompass an individual topic as a whole (*the whole phenomenon*) or only a part of it. Since interdisciplinary considerations push the whole phenomenon into the foreground, in contrast to the far-reaching isolated analyzed aspects in the individual sciences, the term "analysis topic" can usually be utilized synonymously with the term "whole phenomenon."

If one works with interdisciplinarity, several problems soon emerge which are related to this type of scientific pursuit. A few have already been mentioned. One of the main problems is unquestionably that of language. The development of technical terminology is undoubtedly unavoidable if the objects and methods of a science are to be exactly defined. The question which arises stems from how various languages differ from one another. Two cycles of questions exist here: on one hand, there are different types of languages and, on the other, different terms are used. In other words, the utilization of the same term does not guarantee equivalent meaning.

If different disciplines utilize the same terms but define them differently, it can be assumed that they also have different objectives in mind. If indeed this is the case, it may not be beneficial for the comprehension of a phenomenon if one would disregard these different emphases for the purpose of uniform definition.

If two sciences discover that they are describing the same phenomena with different terms, the problem is minimized, but we must still come to an agreement as to which aspects of this phenomenon will be emphasized. Different points of emphasis can be ascribed in almost all cases since the disciplines clearly analyze the phenomenon within the context of different systems. This means that one must mutually strive to understand the other respective approaches as a whole.

In relation to this, there is often talk of a "translation problem" which must be solved: however, this constitutes only one element of the language problem. If different sciences analyze not only *different topics* but *different types of topics* as well, and because of this utilize different languages, then it is questionable whether it is even possible to translate from one to the other. The already mentioned definitions which are generally understood must, therefore, be formulated in order to make the individual terms clear for colleges from other disciplines.

It nearly always becomes problematic when a science has a problem sphere for a topic which it analyzes exclusively, because there is often no translation for some of the subject-specific terms. One must consequently explain the whole relationship in which these terms are used in order to make their meaning comprehensible.

Several possible psychological barriers constitute additional problems, for example, the problem of ingrained thought habits, of which we are usually unaware. The self-evidence with which one approaches problems as an experienced scientist, using a certain technique to arrive at a solution, is surely a factor that is not to be underestimated. Because lengthy explanations are often necessary, the patience of the scientists participating in an interdisciplinary dialog is often tested. An additional problem is the amount of time expended. Often there is also a close personal bond with one's chosen subject, which can become a problem if interdisciplinary collaboration deems that a correction is necessary in the results that were previously viewed as correct. In most cases however, any claim to control would probably be unjustified due to the fact that interdisciplinary problems are by definition subject-overlapping and. therefore, cannot be solved by one science alone. This makes it clear that in the final analysis it is the willingness for discussion which is decisive for the success of a subject-overlapping research project.

Of the items noted, one might conclude that it is especially important for interdisciplinary thought to analyze the terms which are utilized in the description and explanation of phenomena. These terms must be exactly analyzed for content in order to decide whether intersections exist between the analysis topics of the different sciences. Even if it would only be agreed to determine which terms can solely be defined by one special discipline, and which can be clarified interdisciplinarily, progress is already in motion because one can conduct more effective discussions. On one hand, for the same reason, it should be noted which problems each individual scientist deems solvable by one specific theory (and not by another) and on the other, from the onset, it should be clear as to which problems are viewed as solvable only through interdisciplinary solutions. In both cases the opinions may vary because diverse problems exist, or do not exist, for different approaches to solutions. Only then can we further contemplate how the results of scientific inquiry are connected to one another, i.e. how closely the sciences in question are related.

In summary, "the partial scientific unity of the empirical subject" can be formulated as the leading theme for interdisciplinary cooperation, as Helmut Schelsky, the founder of the Center for Interdisciplinary Research in Bielefeld (ZiF) noted in 1966. This means that interdisciplinary methodology takes a different path than the foundation of unity through a single moment, namely that of uniformity in the comprehension of concrete topics (in the broadest sense) *as totalities*. The leading question for interdisciplinary projects should therefore be: "Which questions make up the catalogue for a specific problem and which questions must be answered so that this problem can be viewed as fully solved?" The dissolution of discipline boundaries can also be achieved if the need for a reciprocal complement is recognized.

In order to once again emphasize it, I demand neither a uniform language nor a uniformly theoretical concept for interdisciplinary cooperation, rather merely the conviction that a formulated problem cannot be solved by one science alone. The willingness of scientists to discuss subject-foreign topics and methodologies is the deciding factor. The uniformity, therefore, lies more in the mentality rather than in the method.

In light of these thoughts, I would like to define the term "interdisciplinarily" as *a thought process which overlaps subjects* *thai is oriented on a topic as a whole, leading to a standardization of the comprehension of phenomena in that it connects the partial explanations of different sciences with one another.* The result can either be a partial merging of these individual disciplines into an "interdiscipline," or its direct reciprocal complement, or the cognizance that one is dealing with a transdisciplinary problem which surmounts the framework of the humanities as well as that of the natural sciences. For all of these interdisciplinary exchange possibilities, in an individual case it does not have to be clear how the connections between the respective analysis aspects of different sciences occur: rather it must be unanimously presumed that relationships do exist, so that the parties may continue to search for them together.

If interdisciplinary research is to be effective, it is paramount lhat one first agrees on a generally recognized definition for it, which in my opinion has not occurred until now. Interdisciplinary theory should facilitate concrete interdisciplinary research by clarifying what will be attempted on the whole through a clear classification of different types of subject-overlapping collaboration. One should know exactly what one is doing, i.e. is entering into, if one is to do it well; in other words, one must also realize where the respective difficulties and boundaries lie.

In conclusion, 1 would like to reemphasize that interdisciplinary should not become a predominate scientifically theoretical problem, but rather a connection of knowledge elements should take place in the minds of scientists. The result should be that scientists will understand more of a phenomenon and its complexity than they had previously understood, so that in their future research they do not forget that the partial aspect just being analyzed is in interaction with other partial aspects in an intact total phenomenon.

Biographical Note: The author. Ursula Hübenthal. completed her dissertation on interdisciplinarity at the University of Cologne. She wrote this condensed version for the American audience. The entire dissertation is published in German: *Interdis-ziplinäres Denken: Versuch einer Bestandsaufnahme und Systematisierung* (Stuttgart: Franz Steiner Verlag, 1991).
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