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ON TRANSDISCIPLINARITY

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Abstract. Within the boundaries of transdisciplinary developments, the individual disciplines do not remain what they were, they at least change their methodical and theoretical perspectives. Not just the theories in the narrow sense, also the disciplines themselves get pulled into the process of research and science – in a systematic manner.

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1. Preliminary remark

The concept of transdisciplinarity – which in the context of the philosophy of science I introduced already 20 years ago, as a further development of the concept of interdisciplinarity (Mittelstrass 1987:152–158) – has found a foothold in science and may even be becoming fashionable. It is used not just by science, when thinking about its own research practice, but also by science policy, when trying to give the impression of being knowledgeable in the philosophy of science. More and more often it seems as if transdisciplinarity were self-explanatory, as if its meaning were evident. But this is not at all the case. Though there are attempts to define transdisciplinarity as a method in order to present an elaborated methodology to the sciences, this is rather due to a misunderstanding than to an insight, namely the misunderstanding that transdisciplinarity is something amenable to a formulation in a theoretical form. More on this later. The first question concerns the relation of what we label transdisciplinarity to the disciplinary structure of science. To put it differently: Does disciplinarity, which has accompanied us on our scientific roads, have a future? And is interdisciplinarity, often evoked when addressing the good relations between the disciplines among themselves, no longer enough? What, in any case, is transdisciplinarity, and what would its institutionalisation look like? Let me try to give you a reply under four headings, using some earlier considerations and some examples I have previously given – I do not come up with new ideas every day either (the latest is Mittelstrass 2002:43–54; also 2000 and 2003).

2. Disciplinarity, interdisciplinarity, and the new complexity of science

Our scientific system has become complex in a worrying manner. This is not just valid for the ever-increasing acceleration of the growth of knowledge, but also in organisational and institutional respects. A particularisation of subject matters and disciplines is increasing; the capacity to think in disciplinarities, that is, in larger units of science, is decreasing. The borders of subjects and disciplines, if they are still perceived as such at all, threaten to turn into limits not just of institutions, but also of *discovery*. Accordingly, the concept of interdisciplinarity, often used to oppose this development, is being viewed as a repair tool, which, as time goes by, is supposed to lead to a new scientific order.

But interdisciplinarity is neither something normal, nor something really new, nor the true essence of the scientific order. Where it works, it rectifies misguided developments of science, but also renders apparent that (scientific) thinking in larger disciplinary units has manifestly declined. A whole should again arise out of particularities, both in a systematic as well as in an institutional sense. In what follows, the institutional aspect, aiming at the rebuilding of genuine disciplinarities, will not be addressed primarily, but the role of structures and strategies that span subjects and disciplines in research and, mediately, also in teaching.

In the first instance it is advisable to remind oneself that subjects and disciplines have grown through the history of science, and that their boundaries are thus determined neither by their objects themselves, nor by theory, but by historical growth. Furthermore, their identity is determined by certain objects of research, theories, methods, aims of research, which often do not correspond univocally to the definitions of subjects or disciplines, but which instead overlap these disciplines. This does not just become apparent in the fact that disciplines are being guided by methodical and theoretical ideas which, as with the concepts of a law of nature, of causality, and of explanation, are not determined to belong to any one discipline. It is also evident in the fact that the problems to find solutions for science serves, often do not fit straightforwardly into a disciplinary framework. For instance, the disciplines dealing with the theoretical description of heat were by no means the same in the history of this problem. Initially, heat was conceived of as the inner movement of matter, and thus as an object of physics. In the theory of caloric matter, formulated by Hermann Boerhaave at the beginning of the 18th century, and later developed by Antoine Lavoisier, heat, conceived as matter, becomes an object of chemistry. Finally, with the kinetic theory of heat, heat changes disciplines anew and becomes an object of physics again. So not (just) the objects define the discipline, but our manner of dealing with them in theory.

The example may also be generalised so as to say that certain problems cannot be captured by a single discipline. This is true, in particular, of those problems, as for instance rendered clear in the fields of environment, energy and health, which arise from issues not exclusively scientific. There is, and this not just in these fields, an asymmetry in the developments of problems and scientific disciplines, and this is aggravated as the developments of disciplines and science in general are characterised by an increasing specialisation. But this means that the interdisciplinarity appealed to in this situation is not a ritual of fashion, but arises from constraints deriving from the problems themselves. If the problems, whether scientific or not, do not do us the favour of defining themselves in the terms of a particular discipline or subfield, then special efforts will have to be undertaken, which will normally take us outside our normal subjects or disciplines. In other words, irrespective of the sense in which interdisciplinarity is being understood here, as interdisciplinarity reconstructing larger disciplinary perspectives, or as a real enlargement of the domain of interest of the scientific fields and disciplines, or going beyond scientific fields and disciplines, one thing should be clear: interdisciplinarity, understood rightly, is not merely an alternation between the disciplines, nor is it hovering over them, like Hegel's absolute spirit. Rather, it undoes disciplinary rigidities whenever these obstruct the formation of problems and corresponding research-based actions; in reality, then, it is *transdisciplinarity.*

3. Transdisciplinarity

Whereas scientific cooperation in general means the readiness to engage in cooperation in science, and interdisciplinarity normally means concrete cooperation with a finite duration, *transdisciplinarity* is intended to imply that cooperation will lead to an enduring and systematic scientific order that will change the outlook of subject matters and disciplines. Transdisciplinarity is a form of scientific work which arises in cases concerning the solution of non-scientific problems, for instance the above-mentioned environmental, energy and health care policy problems, as well as an intrascientific principle concerning the order of scientific knowledge and scientific research itself. In both cases, transdisciplinarity is a *principle of research and science*, one which becomes operative wherever it is impossible to define or attempt to solve problems within the boundaries of subjects or disciplines, or where one goes beyond such definitions.

Besides, pure forms of transdisciplinarity occur equally rarely as do pure forms of disciplinarity. These, too, mostly conceive and realise themselves in the context of neighbouring scientific forms, for instance with sociological elements in the work of the historian, chemical elements in the work of the biologist or biological elements in the work of the medical researcher. In this respect, disciplinarity and transdisciplinarity are research-guiding principles or *ideal types* of scientific work, but mixed forms are the rule. What is important is not that science and research should be aware of this, and that productive research is restricted by concerns that are obsolete (and mostly simply due to habit), and thereby focused on narrow areas. Such restrictions neither serve scientific progress, nor a world which, in light of its own problems, wants to use rather than admire science.

In other words, transdisciplinarity overcomes the narrow areas of subjects and disciplines which have been constituted historically, but which have lost their historical memory and their problem-solving capacities due to an excessive specialisation. But it does not lead to new disciplines. That is why it cannot replace fields and disciplines. Transdisciplinarity, secondly, is a scientific principle of work and organisation which spans subjects and disciplines, driven by specific problems, but it is not trans-scientific. The optics of transdisciplinarity is scientific, and it is directed at a world that is more than ever a work of the scientific and technical mind, and which has a scientific and technical nature. Thirdly, transdisciplinarity is a *principle of research*, and not, or at most mediately, namely when the theories themselves follow transdisciplinary research programmes, a theoretical principle. It guides the perception of problems, and their solution, but it does not solidify in theoretical forms. That is why transdisciplinarity is not a method, or even elaborated in the form of a methodology.

What might, from what I have said, still appear very abstract has already found its concrete form in scientific practice, and it is increasingly being fostered institutionally. This applies, for instance, to new scientific centres which have been formed in the USA, in Berkeley, Chicago, Harvard, Princeton and Stanford (see Garwin 1999:3), for instance in Harvard the "Center for Imaging and Mesoscale Structures". It addresses a range of issues which could not sensibly be attributed to any particular discipline. Their objects of research are structures of a certain dimension in general, not any particular objects. Other institutional forms are conceivable, even without gathering them in one building, such as, for instance, in the case of the "Center for Nanoscience (CeNS)" at the University of Munich.

Such Centres are also no longer organised according to the traditional pattern of faculties or schools of physics, chemistry, or biology, but rather according to a transdisciplinary perspective, which, in this case, follows the actual developments of science. That is also true in cases where single problems are being addressed, as for instance in the new "Bio-X" Centre in Stanford (see Garwin, *ibid.*), or the "Center for Genomics and Proteomics" in Harvard (see Malakoff 1999:610–611). Biologists here use sophisticated methods from physics and chemistry to find out about the structure of biologically relevant macromolecules, and physicists like the Nobel Prize winner Steven Chu, one of the initiators of the "Bio-X"-programme, investigate biological objects which may be manipulated with the most advanced methods from physics (see Garwin, *ibid.*). Competencies acquired in individual disciplines remain a fundamental precondition for tasks defined transdisciplinarily, but they no longer suffice to successfully tackle research projects which extend beyond the established fields. This will, in the future, lead to new organisational forms, also besides the establishment of centres such as those mentioned, in which the boundaries between the individual fields and disciplines will fade away.

And this is true of all institutional forms of research and science, not just of research undertaken in universities. In Germany, these constitute a highly differentiated system, which ranges from university research, defined by the unity of research and teaching, and Max-Planck-research, defined by ground-breaking projects in the newest areas of science, to large-scale research, defined by big machinery and fixed-term projects of research and developments (once upon a time openly declared as being of national interest), and Fraunhofer-research, defined by applied research and closeness to industry, to research done in industry, defined by a close connection between research and development.

But the logic of this system, which other countries envy not just because it demonstrates scientific rationality but also exceptional efficiency, is starting to become problematic. That is because it leads to the evolution of independent subsystems whereas really – in the spirit of the above mentioned development of centres – the formation of connections at a low level should be the name of the game, not the expansion of independent systems at a high institutional level. For Germany, but certainly also for other countries, this means that institutionalised research networks of limited duration should take the place of subsystems of science which are isolating themselves more and more from each other. The justification for this is simple, especially from the perspective of science: *The system of science has to move when research is moving.* At the moment, things are exactly the opposite. It is not the research that finds its order, but an order which is given in its subsystems and getting increasingly solidified is looking for suitable research. This order of science is becoming contraproductive. But this should not be the future of research and of a system of science such as the German. As may be seen, the increasing transdisciplinarity of scientific research will, or should, have far-reaching institutional consequences.

4. The unity of nature

In the course of the development of modern science, ideas of a *unity of nature* are again gaining philosophical and scientific importance, as a view of a unitary physical theory – if there is only one nature, then all natural laws must be part of a unitary theory of nature (see Weizsäcker 1971) –, but also as research is increasingly taking a transdisciplinary perspective. If nature does not distinguish between physics, chemistry and biology, then why should the sciences that research it do so, let alone by means of a rigid disciplinary framework? Indeed, the original idea of a unity of nature is shining through the transdisciplinary orientation of modern research programmes. But this idea shall not be the theme here. Instead, I want to talk about how transdisciplinarity is, as a matter of fact, not just a philosophical dream, but instead a part, even an essential part, of the latest scientific research. Let me give you two examples, which I have previously used in this context.

4.1. Nanotechnology

The idea to do research on and reconstruct functional structures of the dimension of 10^{-9} and 10^{-6} metres, that is, individual atoms, molecules and small collections of atoms, originates with a visionary talk given in 1959 by the physicist and later Nobel Prize winner Richard P. Feynman at a conference of the American Physical Society (APS) at the California Institute of Technology in Pasadena (Feynman 1960:22–36). In this talk, Feynman addressed, among other things, the storing and reading of information on very small spaces – and so anticipated a number of currently used lithographic methods –, miniature computers and small 'artificial surgeons' which would move through blood vessels to do their job there, or in the heart. Feynman had been inspired, as he says himself, by biology, in which such small and highly functional structures may already be found. Why shouldn’t it be possible to create them artificially?

Nanotechnologists examine extremely small functional structures (normally biological), for instance membranes, enzymes and other cellular components (‘wet nanotechnology’) and try, furthermore, to experimentally create these structures, using, for instance, semi-conductors (‘dry nanotechnology’) or to simulate their properties on computers (‘computational nanotechnology’). In the creation of nanostructures, scientists from physics as well as chemistry work together closely. Whereas physicists usually begin with a given structure, for instance a surface, which they then process with methods from physics (top-down approach), scientists from chemistry start at the level of atoms and molecules to systematically assemble them (bottom-up approach). All areas of nanotech research are closely interrelated; advances in one area normally entail advances in other areas.

Among the most significant advances in nanotechnology are the synthesis of carbon rings (Fullerenes), the creation of microscopic tubes made out of carbon atoms (see Ajayan and Ebbesen 1997:1025–1062) and the man-made concatenation of a very small number of carbon atoms (see Broglia 1998:371–376). It is remarkable that it is the biologically important carbon atom that gets used as ‘raw material’.

4.2. The quantum-mechanic measurement process and the concept of information

There are some questions and areas of research whose results are not clearly attributable to physics or philosophy. The quantum-mechanical measurement process is one of these. How is it possible that the measurement on a quantum-mechanical system leads to a definite and unambiguous result even if the state measured has been prepared as a superposition of eigenstates of the measured observables? Does the wave function collapse instantaneously, at the moment of measurement, into one of the eigenstates contained in the superposition (as the adherents of the Copenhagen interpretation maintain)? Or do we perceive only a part of the true wave function after the measurement (as for instance the many-worlds and the many-minds interpretations suggest)? Or is the measurement process a ‘real’ process, occurring on an extremely small timescale, whose genuinely non-linear stochastic dynamics goes far beyond the basic assumptions of quantum mechanics and, strictly speaking, even contradicts them (see Ghirardi, Rimini and Weber 1986:470–491)? Other questions pertain to the unifiability of quantum mechanics with the theory of Special Relativity (see Maudlin 1994) and the role of non-local causality in physics. Philosophers, well-acquainted with subtle differences and the handling of concepts in need of explanation (in this context, for instance, non-locality), prove to be useful partners of physics, not always – the will to conceptual clarity often shows itself to be a weak will –, but occasionally. (Of course, it is true that philosophy should not want to solve problems which science, as here physics, is in a better position to solve.)

Information technology too proves to be useful here. According to the Copenhagen interpretation, a quantum system loses information when a measurement is being executed on it. The reason is that the system is in a state of superposition just before the measurement is performed, whereas after the measurement it takes, qua projection, the eigenstate of that operator that has been assigned to the observable to be measured. Any further information of the original state has been lost. After introducing the concept of information into quantum mechanics, the theory of information may be used to further analyse the measurement process, so that a bridge to further applications in technology has been built (for instance, 'quantum cryptography' and 'quantum computing' (see Weinfurter and Zeilinger 1996:219–224)). The research principle of transdisciplinarity does not just concern the collaboration of diverse scientific skills, it also extends to technology.

Thus far my examples. Do they, and what I have said about transdisciplinarity before, imply that we are facing a fundamental paradigm change, in which it is not the theoretical concepts that change – as in the transfer from Aristotelian to Newtonian physics – but in which the order of our scientific knowledge, and thus that of our scientific research and education, is changing fundamentally? It won't get that far, for reasons already mentioned while explaining the concept of transdisciplinarity. The standards of rationality, and with them the methods and forms of theory construction, are not changing. It is the forms of organisation of science and research which are doing so. Once again, transdisciplinarity is a principle of *research and science*, which applies wherever a definition of problems or solutions just through individual fields or disciplines is not possible, or goes beyond them. It is not a *theoretical principle* that changes our textbooks. Just like competence in particular fields or disciplines, transdisciplinarity is a research-guiding principle and a form of scientific organisation, but with the peculiarity that transdisciplinarity removes narrowness due to specialisation which is due not to scientific necessities but to institutional habits.

5. Methodical transdisciplinarity

If it is true that transdisciplinarity is a principle of research and science, not a theoretical principle, nor a method that may be expressed in a methodology, then what is the peculiarity of transdisciplinarity from the *methodological* perspective?

After all, everything science does by way of research has to show the worth of its methods; there is no science without the idea of the methodological, or its realisation. In other words, what is the significance of methodological transdisciplinarity? May something be called methodological without being expressible in a methodology? Let me explain.

I had previously drawn the distinction between sets of problems that are created 'in the world', that is, in the course of social, scientific or technologically shaped developments (as examples, the environment, energy and health care policy had been mentioned), and those which science generates itself, in the course of doing research. In both cases I had talked about the necessity of transdisciplinary extensions. I shall call transdisciplinarity that makes reference to problems foreign to science, *practical* transdisciplinarity, and transdisciplinarity that originates from more strictly scientific problems, *theoretical* transdisciplinarity. As an example of practical transdisciplinarity the case of ecological problems may serve again. Ecological problems require the collaboration of many disciplines, for instance physics, chemistry, biology, climate research, but also sociology and psychology; these contribute with their specialised knowledge to the solution of these problems, and a wise and efficient coordination, but not an extension or transformation of these disciplines, is required. They contribute what they know, but they do not change themselves in their forms of knowledge or methodology.

But precisely this might be required when the issue is to solve problems generated by science itself, namely such problems which, in contrast to ecological ones, are not 'given', and which do not occur in a world common to us, but which have been created by the practice of research or which have been discovered in the course of the development of research. An example of transdisciplinarity in this sense is research on structures, as I have mentioned. The production, analysis, manipulation and practical use of structures of a certain size is not just of interest for physics, chemistry and biology, but also for geology, material science, medicine and computing. For this, the Harvard Centre supplies expensive scientific tools and machines, for instance for the visualisation of nanostructures, and so, as well as in other ways, for instance by providing infrastructure, creates a cooperative atmosphere.

Now, I do not want to distinguish between practical and theoretical transdisciplinarity in the sense that only the latter has a methodological orientation in also a more general sense. A methodological orientation also applies, or better, should apply, where the issue is the solution of practical problems, such that several disciplines need to cooperate for that aim. There are methodical problems here too, and not every collaboration between disciplines is successful. What is it about? Also for this there is an example.

In the year 2000 the Berlin-Brandenburg Academy of Sciences installed a working group that was intended to look at the formation, justification and implementation of *health standards*. The background was the peculiar fact that health is still – in ordinary life just as well as in science – a vague concept, mostly being defined as the absence of disease ('health: see disease'), and then remains peculiarly empty; on the other hand, the desolate condition of the German health system apparently cannot be remedied with the usual patchwork of reforms carried out in the merry go-round of diverse commissions. More fundamental thoughts (for instance, on the concept of health) need to be made and the considerations have to occur at a deeper level – even at an anthropological or moral level. The working group included physicians, lawyers, economists, biologists and philosophers. The results have been published in 2004 under the title “Health Made to Measure? A Transdisciplinary Study on the Foundations of a Sustainable Health Care System” (Gethmann *et al*. 2004).

What were the problems of such a group, and how were they solved in a systematic and methodical manner? In practice, the process consisted of different disciplinarities, represented through different disciplinary competencies, working with and on each other – starting with drafts squarely falling into one discipline, going through repeated revisions from different disciplinary perspectives, finally leading to a common text. The preconditions for this (again in temporal order) were: (1) the unconditional will to learn and the readiness to do without one's own disciplinary ideas. (2) The development of interdisciplinary competence, consisting of a productive immersion into the approaches of other disciplines. (3) The capacity to reformulate one's own approaches in light of the interdisciplinary competence thus gained. (4) The production of a common text, in which the unity of the argumentation (‘transdisciplinary unity’) takes the place of an amalgamation of disciplinary components. In this case, these preconditions were satisfied, and the process succeeded.

These steps, which one may reconstruct methodically, were, to summarise them briefly: first a normal, disciplinary approach, then an encounter of the disciplines, formation of interdisciplinary competence, de-disciplinarisation in the argumentative, transdisciplinarity as argumentative unity. What is crucial is the argumentative perspective, the condition that the entire process took place, in a non-trivial sense, in argumentative space; in this example: the unity looked for, the determination of health care standards and the determination of measures for a good life, had been created going beyond, as well through different disciplines.

In other words, the methodical in this practical transdisciplinarity consists in its argumentative creation and the steps which may be distinguished in the process of creation. This again may also apply to the transdisciplinarity previously described as theoretical, or inner-scientific. That too bases itself on disciplinary competencies, but does not relate them to objects of the disciplines, and thus constitutes a new ‘disciplinarity’, which, with respect to the original disciplines, becomes transdisciplinarity. A research programme, for instance the structural research mentioned before, goes beyond the common disciplinary determinations, and develops its own forms of work and thus also changes the disciplines involved (also due to the constitution of the problem to be solved). That means: Within the boundaries of transdisciplinary developments, the individual disciplines do not remain what they were, at least, they change their methodical and theoretical perspectives. Not just the theories in the narrow sense, also the disciplines themselves get pulled into the process of research and science – in a systematic manner. Precisely this is what is meant with methodical transdisciplinarity.

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References

Ajayan, P. M. and T. W. Ebbesen (1997) "Nanometre-size tubes of carbon". *Reports on Progress in Physics* 60, 1025–1062.

Broglia, R. A. (1998) "Wires of seven atoms – Feynman's very, very small world". *Contemporary Physics* 39, 371–376.

Feynman, R. (1960) "There's plenty of room at the bottom". *Engineering and Science* 23, 22–36.

Garwin, L. (1999) "US universities create bridges between physics and biology". *Nature* 397, January 7, 3.

Gethmann, C. F. *et al*. (2004) *Gesundheit nach Maß? Eine transdisziplinäre Studie zu den Grundlagen eines dauerhaften Gesundheitssystems*. (*Berlin-Brandenburgische Akademie der Wissenschaften: Forschungsberichte,* 13.) Berlin: Akademie Verlag.

Ghirardi, G. C., A. Rimini, and T. Weber (1986) "Unified dynamics for microscopic and macroscopic systems". *Physical Review* D 34, 470–491.

Malakoff, D. (1999) "Genomic, nanotech centers open: $ 200 million push by Harvard". *Science* 283, January 29, 610–611.

Maudlin, T. (1994) *Quantum non-locality and relativity: metaphysical intimations of modern physics*. (*Aristotelian Society Series*, 13.) Oxford: Blackwell.

Mittelstrass, J. (1987) "Die Stunde der Interdisziplinarität?". In *Interdisziplinarität: Praxis – Herausforderung – Ideologie*, 152–158. J. Kocka, ed. Frankfurt: Suhrkamp.

Mittelstrass, J. (2000) *Zwischen Naturwissenschaft und Philosophie: Versuch einer Neuvermessung des wissenschaftlichen Geistes*. (*Konstanzer Universitätsreden,* 205.) Konstanz: Universitätsverlag Konstanz.

Mittelstrass, J. (2002) "Transdisciplinarity – new structures in science". In *Innovative Structures in Basic Research (Ringberg-Symposium 4–7 October 2000)*, 43–54. Munich: Max-Planck-Gesellschaft.

Mittelstrass, J. (2003) *Transdisziplinarität – wissenschaftliche Zukunft und institutionelle Wirklichkeit.* (*Konstanzer Universitätsreden,* 214.) Konstanz: Universitätsverlag Konstanz.

Weinfurter, H. and A. Zeilinger (1996) "Informationsübertragung und Informationsverarbeitung in der Quantenwelt". *Physikalische Blätter* 52, 3, 219–224.

Weizsäcker, C. F. v. (1971) *Die Einheit der Natur: Studien*. Munich: Hanser.