

# DIFFERENTIATION OF SCIENTIFIC DISCIPLINES: CAUSES AND CONSEQUENCES<sup>1</sup>

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## Summary

The scientific discipline as the primary unit of internal differentiation of science is an invention of nineteenth-century society. There exists a long semantic prehistory of *disciplina* as a term for the ordering of knowledge for purposes of instruction in schools and universities. But, only the nineteenth century establishes real disciplinary *communication systems*. They are based on specialization of scientists, on role differentiation in the organizations of science, the emergence of standard forms of scientific publication and the rise of the research imperative which demands an incessant search for novelties. All these structural changes coalesce to the disciplinary community as a new type of communication system in science. After having been established, the discipline functions as the unit of structure formation in the social system of science; in systems of higher education, as subject domain for teaching and learning in schools; and finally as designation of occupational and professional roles. Although processes of differentiation of science have been going on ever since, the scientific discipline as a basic unit of structure formation is stabilized by these plural roles in different functional contexts of modern society. Finally, each individual discipline is embedded into an internal environment of other disciplines. The continuous mutual observation and interaction of these disciplines is the most important factor in the dynamics of modern science.

## 1. Introduction

The scientific discipline functions as the primary unit of internal differentiation in science. In this function, the scientific discipline is an invention of nineteenth-century society. There exists a long semantic prehistory of *disciplina* as a term for the ordering of knowledge for purposes of instruction in schools and universities. But only in the nineteenth century did academics establish real disciplinary *communication systems*. After that, the discipline functions as the unit of internal differentiation in the social system of science, in systems of higher education, as subject domain for teaching and learning in schools, as designation of occupational and professional roles and as *address* for knowledge demands from other functional contexts in society. Although processes of differentiation of science are going on all the time, the scientific discipline as a basic unit of structure formation in science is stabilized by these plural roles in different functional contexts of modern society.

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## 2. Unit Divisions of Knowledge: Classificatory and Archival Functions of Disciplines

*Disciplina* is derived from the Latin *discere* (learning), and it has been used since late antiquity and the early Middle Ages as one side of the distinction *disciplina* vs. *doctrina*. Both terms meant ways of ordering knowledge for purposes of teaching and learning. Often they were used synonymously. In other usages, *doctrina* is more intellectual and *disciplina* more pedagogical, more focused on methods of inculcating knowledge. A slightly later development among the church fathers adds to *disciplina* implications such as admonition, correction, even punishment for mistakes. This concurs with recent interpretations of discipline, especially in the wake of Michel Foucault, making use of the ambiguity of *discipline* as a term always pointing to knowledge and to disciplinary power at the same time. A last relevant context is the role differentiation of teaching and learning and the distinction *doctrina/disciplina* was obviously correlated with it, *doctrina* being prevalent on the side of the teacher, *disciplina* being more necessary on the side of the pupil.

One can still identify the same understandings of *doctrina* and *disciplina* in the literature of the eighteenth century. But what had changed since the Renaissance is that these two terms no longer referred to very small particles of knowledge. They pointed much more frequently to entire systems of knowledge. This went along with the ever more extensive use by early modern Europe of classifications of knowledge and encyclopedic compilations of knowledge in which disciplines functioned as unit divisions of knowledge. The historical background to this was the growth of knowledge related to societal developments such as the invention of printing, the intensified contacts of Europe to other world regions, economic and population growth, and their correlates such as mining and building activities, exploring previously unknown strata of Earth. But, in these early modern developments, there still dominated the *archival function of disciplines*. The discipline was a place where one deposited knowledge after having found it out, but it was not an active system for the production of knowledge.

## 3. Disciplines as Production and Communication Systems

A first precondition for the rise of disciplines as production and communication systems in science is the specialization of scientists and the role differentiation attendant on it. Specialization is, first of all, an intellectual orientation. It depends on a decision by individual scientists to concentrate on a relatively small field of scientific activity, and, as is the case for any such decision, one needs a social context supporting it. Such decisions were rare around 1750 when encyclopedic orientations still dominated among professional and amateur scientists alike, but they gained in prominence in the last decades of the eighteenth century. Second, specialization as role differentiation points to the educational system, which was almost the only place in which such specialized roles could be institutionalized as occupational roles. From this resulted a strong coupling of the emerging disciplinary structures in science and the role structures of the institutions of higher education. This coupling of educational roles and disciplinary designations was realized for the first time in the reformed German universities of the first half of the nineteenth century (**see *Integrating Knowledge in Technology Development***). Afterwards it quickly spread from Germany to other countries. Third, role differentiation in institutions of higher education depends on conditions of organizational growth and organizational pluralization. There has to be a sufficient number of organizations, which must be big enough to have differentiated roles, and these organizations must be interrelated in an ongoing continuity of interactions. In other words, a *system* of universities, being closely interrelated via the invention of disciplinary specialisms and the rapid diffusion of the attendant educational roles functions as the most relevant context of the rise of the scientific discipline. Again, these conditions were fulfilled in nineteenth-century German universities for the first time in history.

The emergence of *communities of specialists* was a further relevant circumstance. In this respect, the rise of disciplines is synonymous with the emergence of *scientific communities* theorized since Thomas Kuhn. Scientific communities rest on the intensification of interaction among participants, on shared expertise, a certain commonality of values, and the orientation of community members towards those problem constellations constitutive of the respective discipline. Modern science is no longer based on the achievements of extraordinary individuals but on the epistemic force of disciplinary communities. That means that modern science is no individualistic enterprise but one founded on restrictions on the individualism characteristic of modernity.

Scientific communities function as the infrastructure of *communication systems*. In this respect the emergence of the scientific discipline is equivalent to the invention of new communication forms germane to disciplinary communities. As the most important case, one can think here of new forms of *scientific publications*. In the eighteenth century, a wide spectrum of publication forms existed; they were not, however, specialized in any way. There were instructional handbooks at the university level, journals of a general scientific nature for a regional public interested in the utility of knowledge, and academy journals aiming at an international public of elite scientists, each covering a wide subject area but with rather limited communicative effects. It was only after 1780 that in France, in Germany, and finally in England, nationwide journals with a specific orientation towards such subjects as chemistry, physics, mineralogy, and philology appeared. In contrast to isolated precursors in previous decades, these journals were able to exist for longer periods of time exactly because they brought together a *community of authors* which did not differ from the community of the readers of the journals. These authors accepted the specialization chosen by the journal; but at the same time they continually modified this specialization by the cumulative effect of their published articles. Thus, the status of the scientific publication changed. It now represented the only communicative form by which, at the macro-level of the system of science—defined originally by national but later by supranational communities—communication complexes specialized along disciplinary lines could be bound together and persist in the long run.

At the same time, the *scientific publication* became a formal principle and expectation structure interfering in every scientific production process. Increasingly restrictive conditions were defined regarding what type of communication was acceptable for publication. These conditions included the requirement of precisely identifying the problem tackled in the article, the sequential development of the argument, a description of the methods used, presentation of empirical evidence, restrictions on the complexity of the argument accepted within each individual publication, an obligatory linkage with earlier communications by other scientists—using citations and other techniques—and the admissibility of presenting speculative thoughts. In a kind of feedback loop, publications, as the ultimate form of scientific communication, exercised pressure on the scientific production process (i.e., on research) and were thereby able to integrate disciplines as social systems.

This reorganization of the *scientific production process* adhered to one new imperative: the *search for novelties*. The history of early modern Europe was already characterized by a slow shift in the accompanying semantics associated with scientific truth, from an imperative to preserve long-established truths to an interest in the novelty of an invention. The success already achieved in organizing traditional knowledge, as well as tendencies towards empirical methods and increased use of scientific instruments worked toward this end (see **Unity of Knowledge in Transdisciplinary Research for Sustainability**). In this dimension, a further discontinuity could be observed in the genesis of the term *research* in the years after 1790. In early modern times, the transition from the preservation to the enlargement of knowledge could only be perceived as a continuous process. In contrast, *research* from about 1800 refers to a fundamental, and at any time realizable, questioning of the entire body of knowledge, which until then had been considered as true. Competent scientific communication then had to be based on research in this understanding. What was communicated in

a scientific publication might legitimately be a small particle of knowledge, as long as it was a new particle of knowledge. Scientific disciplines were established as *research disciplines* based on the incessant production of novelties.

The causal link between scientific disciplines and the organizations of higher education is mediated by two more organizational structures. The first of these are *disciplinary careers*. Specialized scientists as members of disciplinary communities do not only need specialized occupational roles. Additionally there may be a need for careers structured in terms of a succession of these specialized roles. This again is a circumstance which sharply distinguishes eighteenth from nineteenth century universities. Around 1750, one still finds even in German universities hierarchical career patterns which implied that there existed a hierarchical succession of chairs inside of faculties and a hierarchical sequence of faculties by which a university career was defined as a progression of steps through these hierarchized chairs and faculties. One could, for example, rise from a chair in the philosophical faculty to an (intellectually unrelated) chair in the medical faculty. The reorganization of universities since the early nineteenth century completely discontinued this pattern. Instead of a succession of chairs in one and the same university, a scientific career meant a progression through positions internal to a discipline which normally demanded a career migration between universities. This structural change intensified the interactions and competitive relations between universities which competed for qualified personnel and quickly took up new specializations introduced elsewhere. In Germany, such regularized career paths through the national university system were prominently to be observed from around 1850.

This pattern of disciplinary careers is again closely related to *disciplinary curricula* which means that one follows one's disciplinary agenda not only in one's research practice and personal career, but that furthermore there exist institutional structures favoring teaching along lines near to those disciplinary developments which arise at the intellectual frontier of the discipline. The *unity of teaching and research* is one famous formula for this intention, but this formula does not yet prescribe disciplinary curricular structures which would demand that there should be a complete organization of academic studies close to the current intellectual problem situation and systematics of a scientific discipline. Only if this is the case there does arise a *professionalization of a scientific discipline*, which implies that a systematic organization of academic studies prepares for a nonacademic occupational role which is closely related to the knowledge system of the discipline. Besides professionalization as an external consequence there is then the internal effect that the discipline educates its own future research practitioners in terms of the methods and theories constitutive of the discipline. A discipline succeeding in doing this is not only closed on the level of the disciplinary communication processes, it is also closed on the level of socialization practices and the attendant recruitment of future practitioners.

#### **4. The Modern System of Scientific Disciplines**

It is not sufficient to analyze disciplines as individual knowledge producing systems. An adequate understanding has to take into account that the invention of the scientific discipline brings about first a limited number of these disciplinary systems and afterwards many of them arise and interact with one another. Therefore, it makes sense to speak of a modern system of scientific disciplines, which is one of the truly innovative social structures of the modern world.

First of all, the modern system of scientific disciplines defines an *internal environment* (a *milieu interne* in the sense of the nineteenth century French physiologist Claude Bernard) for any scientific activity whatsoever. Whatever goes on in fields such as physics, sociology, or neurophysiology, there exists an internal environment of other scientific disciplines which compete with that discipline, somehow comment on it and its successes and failures, and offer ideas, methods, and concepts. There is *normal science* in a Kuhnian sense, always involved with problems to which

solutions seem to be at hand in the disciplinary tradition itself; but normal science is always expanded upon by a parallel level of interdisciplinary science which arises from the conflicts, provocations, and stimulations generated by other disciplines and their intellectual careers (see ***Incommensurability of Knowledge: Theories and Values***).

In this first approximation, it is already to be seen that the modern system of scientific disciplines is a very dynamic system in which the dynamism results from the intensification of the interactions between a rising number of disciplines. Dynamism implies, among other things, ever-changing disciplinary boundaries. It is exactly the strong coupling of a *cognitively defined discipline* and a *disciplinary community* which motivates this community to try an expansionary strategy in which the discipline attacks and takes over parts of the domains of other disciplines. This was completely different in the disciplinary order of early modern Europe, in which a classificatory generation of disciplinary boundaries meant that the attribution of problem domains to disciplines was invariable. If one decided to do some work in another problem domain this did not mean an extension of one's disciplinary domain but was work done in the domain of another classificatory disciplinary system.

Strongly coupled to this internally generated and self-reinforcing dynamics of the modern system of scientific disciplines is the openness of this system for new disciplinary systems. Here again arises a sharp discontinuity to early modern circumstances. In early modern Europe, there existed a closed and finite catalogue of scientific disciplines which was related to a hierarchical order of these disciplines (for example, philosophy was a higher form of knowledge than history, and philosophy was, in its turn, subordinated to faculty studies such as law and theology). In modern society, no such limit to the number of disciplines can be valid. New disciplines incessantly arise; some old ones even disappear or at least become inactive as communication systems. There is no center and no hierarchy to this system of the sciences. Nothing allows us to say that philosophy is more important than natural history or physics more scientific than geology. Of course, there are asymmetries in influence processes between disciplines, but no permanent or stable hierarchy has ever been derived from this.

The modern system of scientific disciplines is a global system today. This indicates a significant difference from the situation of the early nineteenth century, in which the rise of the scientific discipline seemed to go along with a strengthening of national communities of science. This nineteenth-century nationalization effects may have been occasioned by restrictions of the communicative space in newly constituted communities being an effective strategy of system building. But the nationalization of science has since proved to be a temporary phenomenon only, and the ongoing dynamics of disciplinary and (sub)disciplinary differentiation in science probably is the main reason why national communication contexts are no longer sufficient infrastructures for a rapidly growing number of disciplines and subdisciplines.

## **5. The Future of the Scientific Discipline**

The preponderance of subdisciplinary differentiation in late twentieth and early twenty-first century society is the reason most often cited for the presumed demise of the scientific discipline postulated by a number of observers. But one may object to this hypothesis on the ground that a change from disciplinary to subdisciplinary differentiation processes does not at all affect the drivers of internal differentiation in modern science: the relevance of an internal environment as decisive stimulus for scientific variations, the openness of the system for disciplinary innovations, the nonhierarchical structure of the system. Even if one points to an increasing importance of interdisciplinary ventures (and to problem-driven interdisciplinary research) which one should expect as a consequence of the argument on the internal environment of science, this does not change the fact that disciplines and subdisciplines function as the form of consolidating interdisciplinary innovations. Any interdisciplinary field which really establishes itself in science normally will take the route of

becoming a new discipline itself. Interdisciplinarity and transdisciplinarity do not at all conflict with the disciplinary structure of science. Instead, they function as the modes of knowledge transfer and innovation transfer in a cognitive world structured by disciplinary social systems (see **Unity of Knowledge in Transdisciplinary Research for Sustainability**). And, finally, there are the interrelations of scientific disciplines with the external environments of science, which, in twentieth and twenty-first century society, are plural environments based on the principle of functional differentiation of society. Social systems in the nonscientific environment of science are dependent on sufficiently stable addresses in science if they want to articulate effectively their needs for inputs from science (see **Institutional Changes for Transdisciplinary Research and Learning**). This is true for the educational environment of science, which, since the nineteenth century, organizes school and higher education curricula in disciplinary or interdisciplinary terms (see **Educational Programs for Transdisciplinary Learning; see Transdisciplinarity and Disciplinarity in the University of the Future**), for role structures as occupational structures in the economic environment of science, and for many other demands for scientific expertise and research knowledge which always must be able to specify the subsystem in science from which the respective expertise may be legitimately expected. These interrelations based on structures of internal differentiation in science which have to be known by outside observers are one of the core components of modern society. Since the second half of the twentieth century, modern society is therefore often described as *knowledge society* (see **Integrating Knowledge in Technology Development**), and one of the main understandings of this formula is the society-wide relevance of disciplinary knowledge in many nonscientific functional domains of society. This never could have occurred if science had not specified its internal structures via disciplinary differentiation.

## Glossary

- Archive:** Place to deposit something of historical and of potential future relevance, for example elements of knowledge.
- Classification of knowledge:** Systematic way of ordering knowledge via an order of terms which allows to find knowledge by looking at these terms.
- Communication system:** Social system built from communicative acts and their interrelations.
- Educational system:** Function system in society, specialized on educating members of society; scientific institutions often are part of the educational system.
- Epistemic community:** Global community of members, built around some set of cognitive and normative commonalities.
- Function system:** Global social system, specialized around a certain function in society, for example political power, scientific research, religious communication, economic transactions, etc.
- Interdisciplinarity:** Kind of knowledge production in science based on coordinated contributions from at least two scientific disciplines.
- Knowledge society:** Description of modern society which says that modern society is characterized by a plurality of sources of knowledge production, among which science is only one such source of knowledge production.
- Normal science:** Name for a production process in modern science, in which by theoretically guided predictions one supposes already to know the knowledge one is trying to find in a search process.
- Novelty:** Social expectation in communication processes in science which demands that the newness of information is decisive for something being acceptable as a scientific communication.
- Production system:** Kind of social system which arises by producing all of its components by its own operations; in systems theory this is called “autopoiesis.”
- Professionalization:** A knowledge system is strongly coupled to an occupational role in society, the exercise of the respective occupational activity being restricted to those persons having

undergone systematic education in the knowledge system beforehand.

**Publication:** Most important form of communication in science, especially as publication of scientific papers in specialized journals.

**Research:** Since the early nineteenth century, the term for any systematic and methodical search for scientific knowledge which aims at producing novelties.

**Scientific community:** Social core of a scientific discipline, unified by disciplinary norms and cognitions.

**Scientific discipline:** Social and cognitive unit of knowledge production in science.

**Specialization:** Concentration on a specific domain of scientific activity, for example physics or history.

**Unity of teaching and research:** Norm in university teaching which demands that this teaching has to be based on recent research knowledge or even has to participate in processes of scientific knowledge production.

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## **Biographical Sketch**

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