Chapter 3
Scientific Communication and Codification

In the sociology of scientific knowledge and the sociology of translation, heterogeneous networks have been studied in terms of *practices* and so-called *actor-networks*. However, scientific practices are intellectually structured by codes. Cognitive structures interact and co-construct the organization of scholars and discourses into research programs, specialties, and disciplines. The intellectual organization of the sciences adds to and feeds back on the configurations of authors and texts. The social, textual, and cognitive sub-dynamics *select* upon each other asymmetrically. Selections can further be selected for stabilization along trajectories and then also be globalized—symbolically generalized—into regimes of expectations.

In his seminal study of the Sociology of Scientific Knowledge (SSK), David Bloor (1976, at p. 2) argued that "*knowledge for the sociologist is whatever men take to be knowledge*." Consequently, the "strong program" in the sociology of science introduced the so-called "principle of symmetry": a sociological explanation should be able to explain both true and false knowledge as human beliefs. From this perspective, scientific knowledge can no longer be considered as "true" belief, different from other knowledge or beliefs (Barnes, 1974; cf. Fuller, 2018). Bloor (1982) argued that even rules of logical inference in mathematics derive their truth from social negotiations and human beliefs.

SSK posited that in *practices* the cognitive is always social, and vice versa. The dimensions of the cognitive and the social are integrated and, from this perspective, not to be distinguished. Sociocognitive (inter-)actions shape the social *and* the cognitive at the same time (Collins, 1983). Therefore, analysis should not be pursued in terms of dimensions like "cognitive" versus "social" or "internal" versus "external." From the perspective of SSK, one could not accept an *ex ante* disciplinary division of labor among the history, philosophy, or sociology of science. The analysis is pursued instead in terms of the subject matter.

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This strong program builds on Kuhn's (1962) theory of paradigms as language games (Winch, 1958; Barnes, 1969). The focus on content led to descriptions of the world of science that were empirically richer than those provided by previous traditions in the sociology of science (Merton, 1942; 1973; cf. Barnes & Dolby, 1970). For example, it was no longer acceptable to describe a specialty only in terms of the organizational variables of a scientific community (Crane 1969 and 1972; Whitley 1984). Nor could a specialty be operationalized in purely epistemological terms, such as a set of theoretical questions linked to relations among arguments, observations, and inferences (Hesse, 1980); nor could it be adequately described as a body of literature or a communication structure (Price, 1961). As with all major concepts in science studies, it was henceforth necessary to develop the definition of "specialty" by relating the perspectives of social structure, cognitive contents, and scientific literature. The potential tensions among these different evaluations were "heterogeneously engineered" by both the participants and the analysts into *practices* which operate as "mangles" (Pickering, 1995).

From this perspective, the analyst has no choice but to "follow the actors" like an ethnographer (Latour, 1987). Scholars working in Actor-Network Theory (ANT)—originally a Parisian program developed at the École des Mines—further radicalized the symmetrical approach by including "non-humans" in their descriptions (Callon et al., 1986; Callon and Latour, 1981). For example, in his study of the introduction of scientific principles of breeding into fishery, Callon (1986) argued that the relevant "actor-network" consists of the oceanologists whose aim is to transform fishing into "aquaculture," the science of oceanology which imposes problem-formulations, the fishermen who defend their interests, *and the scallops* who breed and enter the networks of both the fisherman and the analysts studying them. When these different elements are aligned into an "actor world," the system can be "translated" at an "obligatory passage point." A translator spokesman is needed to provide the translation.

Note that in this "sociology of translation" the cognitive or natural constraints on the situation are not analyzed *as if* they acted as constraints; this program is not an heuristic. Instead, the actor-network is constructed as a next-order unit of performance on the basis of what these authors call "relational strength"; heterogeneous dimensions are homogenized in a pan-semiosis (Hagendijk, 1996). In other words, the substantive heterogeneity in the subject of study is not addressed in terms of analytically different dimensions, but in terms of an assumed coincidence, congruity, and symmetry between *explanandum* and *explanans* within the subject matter. As against the natural sciences, a sociologist in the ANT tradition cannot avoid being part of the networks under study.

From the perspective of ANT, an analyst knows a priori that the relations in the actor-network are mutual and symmetrical. Nothing can ultimately be explained, and the sole purpose of the analysis is to tell a convincing story (Latour 1987; Collins and Yearley 1992). Testing is not statistical, but in practices, and in terms of "robustness" (Rip, 2010). Consequently, the actor-network is not only an *empirical* category; this program claims also to provide an answer to the *methodological* problem of analyzing "heterogeneity" (Akrich et al., 2010). Actor-networks cannot be explained other than by describing them and thus becoming enrolled into them.

3.1 The Status of Cognitive Structures

In my book *The Challenge of Scientometrics* (1995), I argued against ANT and SSK that authors, texts, and cognitions cannot be reduced to one another. One can distinguish between the textual, cognitive, and social dimensions of the units of analysis under study. The variation in each dimension can be aggregated using grouping rules in the other two dimensions. For example, authors can be grouped in terms of substantive specialties, or in institutional terms such as departments and universities.

By considering three dimensions as orthogonal, a scheme for science studies can be unfolded (Fig. 3.1). This model allows for interactions at each moment in a static design, and for dynamic "feedbacks" and "mutual shapings" among the social, textual, and cognitive (sub)dynamics over time. Over time, a "triple helix" of cognitions, texts, and agents can thus be envisaged. Different meanings can be expected on the basis of different grouping rules. For example, one can distinguish between the meaning of a publication in cognitive terms at the field level and in social terms at the level of the research group.

Note that the implied assumption of the *analytical* independence of the cognitive dimension does not imply a return to older traditions in the philosophy and the sociology of science. Traditionally, the context of discovery and the context of justification have been conceptualized as two separate domains, to be pictured spatially as parallel planes and studied by distinctive scholarly traditions (that is, the history and philosophy of science for the context of justification *versus* sociology for the context of discovery). The three-dimensional scheme of Fig. 3.1, however, provides

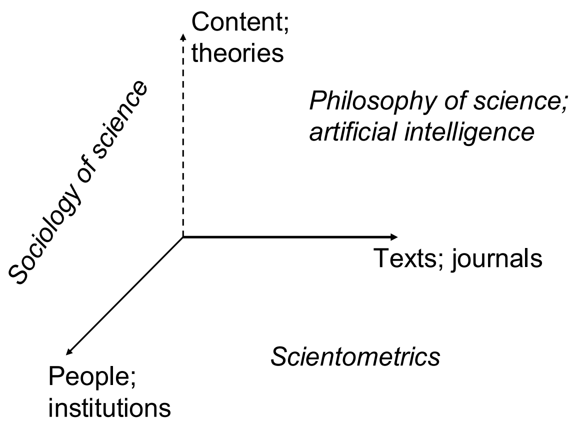

Fig. 3.1 Three main dimensions in the dynamics of the sciences; adapted from Leydesdorff (1990)

room for adding a third (textual) dynamics to the social and intellectual organization of the sciences.

I have used dashes for the vertical axis in Fig. 3.1. Unlike texts and authors, cognitions cannot be found “out there” without taking a reflexive turn. Still, the cognitive dimension provides grouping rules for organizing texts and authors in terms of research programs, specialties, and disciplines. These grouping rules are not grounded in nature, but constructed. In order to address the cognitive dimension empirically, a reflexive specification is first needed. The cognitive dimension—or, in other words, the third helix—leads us to the question of how codifications organize texts and people.

3.2 Codification in Communications

When a scientific paper is presented—for example, at a conference—the content has first the status of a knowledge claim. When the paper is subsequently reviewed and published in the literature, the knowledge claim is validated, and thus the status of both the paper and its content is changed (Myers, 1985). Peer review is, among other things, expected to evaluate the paper under study for its quality, and while doing so it ascribes an expectation of quality to the paper as a construct. In other words, this process constructs a cognitive outcome in addition to a social one.

What has been added to the article during the social process of peer reviewing? Building on Parsons’s (1963a, 1963b) concept of “symbolically generalized media,” on the one hand, and Husserl’s (1929) notion of “horizons of meanings,” on the other, Luhmann suggested that the coding of the communication implies a domain-specific selection. In other words, the paper goes through a process of recursive selections whereby it is invested with symbolic value. The status of the paper is changed from a knowledge claim into a contribution to be stored in the knowledge base for future reference.

The code of communication operating specifically in the sciences was characterized by Luhmann as a selection on whether the claim in the paper is “true” or not. I prefer Simon’s (1973) characterization of the code of science in terms of heuristics (truth-finding) and puzzle-solving (see Chap. 1). The codes legitimate specific selections (cf. Zuckerman, 1999). The *expectation* of a selection environment drives the competition, and this encourages participants to focus on the content of a communication rather than its social conditions. Although the codes themselves are also constructed historically, they operate as selection mechanisms at another level and with a different frequency than the knowledge claims that were submitted.[1] Criteria operate globally and are reproduced locally by the specification under historical circumstances, that is, by the acceptance or rejection of the knowledge claims in the papers under review (Fujigaki, 1998).

[1] From an evolutionary perspective—to which I return in a later chapter—the knowledge claims can also be considered as phenotypical and the codes as genotypical (Hodgson & Knudsen, 2011).

The construction of these mechanisms as a basis for a scientific culture has taken centuries. For example, the scientific journal was an invention of the seventeenth century (Price, 1961), while—as noted in Chap. 2—the modern citation was invented only at the end of the nineteenth century. However, the codes should not be reified. They remain tendencies in the communication, constructed and therefore expected to change. In the case of a crisis in the communication, for example, the codes may also need to be redefined. Thus, the networks of communications develop an eigen-dynamics which is partly (that is, reflexively) accessible and partly latent for the communicators who carry the communications (Lazarsfeld & Henry, 1968; Von Foerster, 1982).

3.3 Beliefs *versis* Rationalized Expectations

The strong program of SSK emphasized the symmetry of true and false statements with reference to Durkheim's (1912) analysis of the forms of religious life and to Mary Douglas's (e.g., 1970) anthropology of groups and grids. From this perspective, the sciences are considered as *belief* systems attributable to agents or groups of agents. In my opinion, the sciences are socially constructed as discursive systems of rationalized expectations. Rationalized expectations are attributes of a discourse, i.e., relations among people. In other words, the units of analysis are different: beliefs are attributes of agents at the nodes of a network, whereas expectations are discursively rationalized communications. The rationalization is an attribute of the exchanges at the links.

In controversy studies, the assumption that the sciences may also function as belief systems can be empirically fruitful. In a number of other respects, however, the sciences operate differently from religions. In contrast to a system of expectations, a religion tends to be organized hierarchically with reference to a single or dominant meaning (e.g., a religious Truth) and therefore normatively integrated in terms of what is right and what is wrong. In scholarly discourse, however, the disbelief in a scientific "truth" no longer creates a schism as between religious communities in the Middle Ages; nowadays the articulation of other perspectives may raise and enrich research questions.

In other words, the mechanisms of the communications are different. Modern sciences are no longer worldly religions organized hierarchically for celebrating the "Truth," but they are discursive constructions serving heuristics—that is, truth-finding. However uncertain and variable the coding may be, the yardsticks for controlling the truth of scientific statements are different from normative integration into individual or collective beliefs.

New forms encompass (and potentially enrich) the older ones which may continue to serve as subdynamics in a more complex arrangement. Both integration into organizations and differentiation among the self-organizing codes can be expected. From this perspective, integration is a recursive network function, namely the specific one of providing a basis for action. Organization has to be carried historically by agency

(Achterbergh & Vriens, 2009). The globalizing and self-organizing functions can be expected to provide different meanings along other and potentially orthogonal dimensions in the vector space of Fig. 3.1 (cf. Simon 1969).

A hierarchy is based on integration, as in a dendrogram; differentiation adds a degree of freedom: more than a single hierarchy is then possible. In other words, each function self-organizes a different hierarchy. The different hierarchies can be expected to disturb one another, leading to a "fractional manifold" of partial hierarchies (Ivanova & Leydesdorff, 2014). Whereas a hierarchy is shaped when relations are organized into a dendogram-like structure, the resulting network contains a structure with potentially an alphabet of dimensions.

In the longer run, the sciences can allow for normative and institutional control over the conditions of the communication (e.g., resource allocations), but not over the substantive and reflexive contents of these communications; the dynamics are from this perspective self-organizing and functionally differentiated in terms of codes. Scientists have a particular need to incorporate this cognitive differentiation enabling them to change perspectives. One needs room to explore counter-intuitive interpretations or theoretically informed hypotheses ("conjectures"; Popper, 1963) that one may wish to change with hindsight.

This differentiation from normative integration has been a functional requirement for the further development of natural philosophy, that is, the new sciences. The crucial conflict between self-organization and normative control on the basis of religious or political convictions was fought in Western Europe between the appearance of Galileo's *Dialogo* in 1632 and the publication of Newton's *Principia* in 1687. From that time onwards—that is, since the so-called "Scientific Revolution" (e.g., Cohen, 1994)—the further differentiation of scientific communications has been institutionalized in the social system of science in both Europe and elsewhere (cf. Graham, 1974; Lecourt, 1976; Merton, 1938, 1942).

Why was the new "natural" philosophy able to drive this development? By reconstructing "nature" in experimental settings—that is, on the basis of a model—an observation is transformed into an instantiation with reference to an expectation. Insofar as this reconstruction proves successful, the previous ("natural") order can be replaced with a new construct (Shapin & Shaffer, 1985). In principle, the new paradigm can thus overwrite the older one and lead to new practices. This replacement may be a sudden event (an "avalanche") or a gradual development. Once the old paradigm is replaced by a new one, the former tends to lose its meaning and relevance for the further development of the communication.

The evolutionary dynamics of the sciences is both driven by and driving processes of modernization at the level of society. Marx (1848) famously characterized this process of modernization as "all that is solid, will melt into air" (cf. Berman, 1982). However, "air" is not sufficiently specific; what is in the air needs to be specified in terms of coordination and selection mechanisms. "All that is solid" can be considered for reconstruction; a phase space of other possibilities can be envisaged.

3.4 "Structuration" by Expectations

In his "structuration theory," Giddens (1979, 1984) offered another way to discuss structures in terms of the expectations of agents. According to Giddens, structures exist only as memory traces that can be instantiated in action (Giddens, 1984, p. 177). Structures can be considered as providing rules and resources which can be instantiated. However, structure, according to Giddens (e.g., 1979, at p. 64), exists outside "time and space" as "absent differences" that, in his opinion, cannot be studied empirically. He argued that sociology should retain a firm focus on observable action and empirical explanation.

How can individual memory traces be coordinated? According to Giddens, this question is not answerable. The invocation of "magical explanatory properties of social reproduction" could lead us back to abstract systems theory and (neo-)Marxism (Giddens, 1979, at pp. 73–76). As he emphasized:

> There can be no doubt about the sophistication and importance of the work of some authors currently endeavouring to develop Parsons's work in novel ways, particularly Luhmann and Habermas. But I think it as necessary to repudiate the newer versions of Parsonianism as I do the longer established varieties of non-Parsonian structural sociology. (1984, at p. xxxvii).

In Giddens' "structuration theory," the "duality of structure" is considered as a "virtual"operation. Since this virtual operation cannot be studied empirically, a *methodology* is suggested for relating institutional analysis to the analysis of strategic conduct: the one narrative can be used as a *context* for informing the other; structure is present in action and actions can be aggregated into structures. However, the two narratives remain juxtaposed by "bracketing" the one perspective as contextual when focusing on the other (Giddens, 1984).

Although Giddens (1976, at p. 162) acknowledged a possible interaction among the memory traces leading to a "double hermeneutics"—the roles of observers and participants can be combined and/or distinguished—he avoided theorizing the "second contingency" of expectations itself as a possible structure. From his perspective, this second contingency falls outside the empirical domain studied in sociology. As the author (1979, pp. 81f.) explained:

> The communication of meaning in interaction does not take place separately from the operation of relations of power, or outside the context of normative sanctions.[…] Practices are situated within intersecting sets of rules and resources that ultimately express features of the totality.

However, the focus should remain, in Giddens' opinion, on observable actions. institutions, and instantiations of structure. Although structure is implicated in the reproduction of social systems, it cannot and should not be studied as such *because it is absent*.

In my opinion, this inference does not follow: Why would one not be allowed to formulate hypotheses about a second contingency in social structures? The formulation of expectations may be helpful in the design and then lead to the specification of relevant observations. Might what is absent (the "zeros") not be equally or perhaps more interesting than what happens to be the case (Deacon, 2012)? In social network analysis, for example, one also studies missing links or structural holes (Burt, 1992; cf. Breiger, 2010).

I agree with Giddens that one should avoid "abstract systems theory" without an agenda for empirical operationalizations; but this is a different issue from denying legitimacy to the study of structures in expectations. Structures can be expected to operate as selection and coordination mechanisms, and observations can serve to test hypotheses about the dynamics of expectations.

3.5 Biological and Cybernetic Metaphors

The crucial step, in my opinion, is to join theorizing with an empirical perspective allowing for the exploration of new questions and the interpretation of empirical results (Merton, 1948). A theory without this perspective can be considered as too "grandiose" for sociological research and analysis. According to Giddens (1979, p. 237), "models of biological systems, especially those tied to the notion of homeostasis, will not suffice to illuminate some of the key issues posed by the analysis of social systems."

In addition to the specter of social Darwinism, biological models indeed tend to abstract from the individual in favor of an analysis at the level of populations. Giddens noted that Parsons & Dupree (1976) had already signaled the potential of cybernetics for developing a richer framework in which the relations between genotypes and phenotypes can be studied in a context different from biology; for example, in terms of computer simulations and linguistics. However, Parsons did not further elaborate this perspective. In an email conversation at the list of the American Cybernetics Society (dated 9 June 2010), Klaus Krippendorff suggested avoiding "systems theory" given the biological origin and epistemology of the idea of "systems." Why should the social be systemic? In Krippendorff's opinion, cybernetics offers an alternative:

> Gregory Bateson was one of the first to recognize the evolutionary epistemology that cybernetics offered him and wrote several papers about the revolutionary changes cybernetics offered. Being less tied to what exists gave cyberneticians an extraordinary creativity. Indeed, cyberneticians have been amazingly unconstrained in developing and elaborating novel concepts, starting with circularity, self-reference, information theory, all the way to several reflexive moves that have transformed cybernetics.[…] Cybernetics' contribution to information theory opened the door to theories of variety, to understanding evolutionary processes (mutation and selection of what doesn't work), and of course digitalization and computation which systems theories could not address, largely because their discourse directed systems theorists to shared wholes, away from perturbations, diversity, and *building computational realities.*

From the perspective of cybernetics, theoretical reification into a presumably global system is outdated. The analysis can instead be pursued in terms of dynamics and subdynamics, which one is able to hypothesize. The status of theorizing is then more modest; theories serve us as heuristics for solving problems (Simon, 1969; Newell & Simon, 1972).

3.6 Sociocybernetics

How do these considerations lead to a sociology of science that is different from the sociology of scientific knowledge or Luhmann's social-systems theory? The shift from historical observations to the specification of expectations seems crucial to me. Theories can be tested, and historicism can be avoided; cases that actually occurred can be used as examples of what could have occurred. However, the historical narrative cannot by itself inform us about the distribution of instances that one would have expected.

Despite Luhmann's programmatic intention to "de-ontologize" sociology (e.g., Luhmann, 1990, p. 67), one can find in his texts remainders of a tendency to reification. Differentiation, for example, is labeled "functional," whereas differentiation can also be dysfunctional (Mitroff, 1974). As noted, Künzler (1987, p. 323) argued that Luhmann understood code as a binary duplication rule much like DNA.[2] Statements do not have to be wholly true or false, but can be true to variable extents.

In his book entitled *Social Systems*, Luhmann ([1984, at p. 30] 1995, at p. 12) went one step further in the direction of a biological model by explicitly assuming that "systems are given." As he put it:

> The following considerations assume that there are systems. Thus, they do not begin with epistemological doubt. They also do not advocate a "purely analytical relevance" for systems theory. The most narrow interpretation of systems theory as a mere method of analyzing reality is deliberately avoided.[…] In systems theory, scientific statements are not only statements, but they also refer to the real world.

Although one can place the emphasis in the first sentence of this quotation on "assume," the given-ness of systems in "the real world" raises ontological questions. At other places, however, Luhmann (e.g., 1990, p. 76) emphasized that "reality itself remains unknown": each self-referential system generates its own "transcendental"environment ("bubble"); a self-organizing system can "observe" in terms of the distinctions that it has learned to make. He formulated for example:

> The effect of the intervention of systems theory can be described as a *de-ontologization of reality.* This does not mean that reality is denied, for then there would be nothing that operated—nothing that observed, and nothing on which one would gain a purchase by means of distinctions. It is only the epistemological relevance of an ontological representation of reality that is being called into question.

It seems to me that Luhmann alternated between two repertoires: one of general systems theory and another of socio-cybernetics as a specifically sociological branch of systems theory. The sociological perspective is elaborated using historical studies. The case materials are "observed" by reading and analyzing texts (e.g., Luhmann, 1982). However, the specifically human component of using language—as reflected

[2] Why should the codes be binary and not allow for grey shades? When discussing this issue, Luhmann (1986, p. 2; 2004, p. 116) argued (in a discussion with Maturana) that a woman can be either pregnant or not pregnant, but not half-pregnant. However, this is again a biological argument. Culturally, one can also be pregnant with ideas.

in *discourse analysis and hermeneutics*—is backgrounded. The purpose remained eventually to develop a *general* systems theory. As Künzler (1987, p. 331) put it:

> Language haunts as a foreign body in systems theory as a supertheory, and in its sub-theories, emerging as a surprise in nebulous passages in order to vanish as surprisingly, and is obviously perceived as a disturbing element and one which also cannot be eliminated.

Habermas (1986) identified this model in a sharp critique, as follows:

> The flow of official documents among administrative authorities and the monadically encapsulated consciousness of a Robinson Crusoe provide the guiding images for the conceptual uncoupling of the social and psychic systems, according to which the one is supposedly based solely on communications and the other solely on consciousness.[…].
>
> What a burden is assumed by a theory that divides up linguistic structures that cover both the psychic and the social dimensions into two different systems. (p. 378f.)

In summary: Luhmann's theory can also be read as a meta-biology. Because of the common roots in systems theory, Luhmann tends to model language after "languaging," that is, a form of behavior (Maturana, 1978). The languaging agents—human beings—can be considered as interacting "observers" (von Foerster, 1982).[3] However, one cannot infer from this formal definition of an *observer* to the content of an *observation* (see Chap. 1).[4] The content itself is the cultural object.

In summary, my approach is fundamentally dualistic as opposed to the holistic approaches nowadays prevailing in artificial intelligence and biology (e.g., Damasio, 1994; Sherman, 2017). In my opinion, the specification of expectations is not "epigenetic" (e.g., Ramstead et al. 2017, p. 12; see Chapter Ten), but constitutive for inter-human communications in general, and scientific communications in particular. The logic of an emerging system can increasingly be different (that is, "bi-furcate") from its genesis.[5] The story about the historical genesis may serve didactic purposes, but should not be confused with the specification of theoretical content. Genesis is not validity; historicism were to be avoided.

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[3]Luhmann (e.g., [1993] 1999) turned to George Spencer Brown's (1969) book *Laws of Form* to legitimate this "grounding" of his theory in "observations." However, *Laws of Form* cannot be used for this purpose: the "observer" mentioned by Spencer Brown is only one possible consequence of the operations of distinguishing and designation.

[4]Spencer Brown (1969, at p. 76) concludes (on the final page of this study) that "an observer, since he distinguishes the space he occupies, is also a mark," and he adds: "a distinction drawn in any space is a mark distinguishing the space. Equally and conversely, any mark in a space draws a distinction.[…] We see now that the first distinction, the mark, and the observer are not only interchangeable, but, in the form, identical." Note that "in the form" means (à la Aristotle) that this observer can be a cause of content—i.e., observations.

[5]See Leydesdorff (2006, pp. 169 ff.) for an explanation and derivation of bifurcation and morphogenesis in terms of reaction–diffusion dynamics.

3.7 Concluding Remarks

I have argued in this chapter that—unlike DNA—non-biological codes in communications structure expectations in relation to horizons of meaning without being hard-wired. The codes are theoretically constructed and reconstructed in history; for example, in action. A cultural evolution is thus shaped on top of biological evolution. The exchange and sharing of expectations in the second contingency can be considered as the *differentia specifica* of inter-human communication.

The second contingency evolves as interacting expectations. A reflexive dynamic of meaning and intentionality is thus added to the first contingency of observable actions. As against biological systems in which operational closure can be structural, translations among codes remain possible across boundaries in social systems. The differences among the codes do not "exist" physically and the codes do not need to be organized into a hierarchy. The codes can be expected to span a space of possibilities of which only some are realized in each instance As Latour (1988, at p. 164) argued, there is no need to assume an *ex ante* hierarchy; order is established *ex post*.

Furthermore, I have argued in this chapter that cognition is manifested at the social level as discursive knowledge. The development of discursive knowledge is guided by latent codes in the communications. The codes remain socially constructed, but tend to develop into a control and coordination mechanism that can organize authors and texts selectively. While the instantiations can be observed, the codes selecting upon the observables can only be hypothesized.

In my opinion, Luhmann's theory read as socio-cybernetics provides us with a heuristic for exploring the dynamics of expectations. In order to proceed to empirical research and testing, however, one needs additionally a theory of measurement. Can this model of interacting communications and the self-organization of meaning be made compatible with Shannon's information theory as a measurement theory? Is it possible to specify how the processing of information and meaning are related?

In the next chapter, I first extend the Shannon model of communication into a complex systems model in which communications are differentiated. My long-term objective is to bridge the gap between Luhmann's sociological focus on meaning processing and Shannon's focus on information processing by decomposing the problem using Simon's (1973a) model of complex systems that are differentiated both vertically and horizontally. A complex dynamic of (horizontal) differentiations among the codes versus (vertical) integration in instantiations can be expected, which will be further specified in Chapters Eight and Nine in terms of weakly and strongly anticipatory systems (Dubois, 2003).

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