FOREWORD

Shortly after Charles Darwin published his seminal work *On the Origin of Species* in 1859, the concept of "evolution" entered nineteenth century thinking, and soon became a general metaphor to describe developmental processes in many scientific disciplines. One of the first scientists to adapt to Darwinian ideas was August Schleicher, who, in an open letter to Ernst Haeckel (1863), pointed out striking similarities between linguistic and biologic descent. He was also the first to present family trees as evolutionary trees, exemplified by postulating a common ancestor of all Indo-European languages. In 1871, Darwin incorporated these proposals in his book entitled *The Descent of Man and Selection in Relation to Sex*, in which he placed strong emphasis on the importance of natural selection in linguistic evolution.[1] The on-going debates about evolution in biology and comparative philology had major cross-disciplinary impacts on theory building, both in natural and cultural sciences, and finally gave rise to "Universal Darwinism" (Dawkins 1983). Within the framework of a comprehensive "generalised theory of evolution," the Darwinian principles of reproduction, variation and selection have gradually become detached from their biological substrate, being construed as abstract properties of dynamic systems (for summaries see Gontier et al. 2006; Schurz 2011; Mesoudi 2011; Brinkworth et al. 2012; Ruse 2012; Sydow 2012).

Recently, there has been an increase in the number of critics of universal or "generalised Darwinism", who view it "as an overarching research strategy" (Levit et al. 2011). Specifically, critics have questioned the explanatory power of this approach, which is based on the assumption of a fundamental homology between evolution in nature and the evolution of any kind of culture.

While Darwinism has undergone many changes, and shown up in many facets, there remains an outstanding common feature in its history spanning more than 150 years; since the very beginning, branching trees have been the dominant scheme for representing evolutionary processes. In the analogy with kinship relations in a family tree, this scheme exclusively models evolution as vertical inheritance. However, the scheme does not cover lateral transfer, that is, the mixing or hybridizing species or languages. To describe this latter phenomenon, a reasonable approach seems to be the use of the network metaphor.

Different from powerful bifurcating tree graphs, the use of network graphs to represent the development of species and languages has only recently received increasing interest in the fields of science and humanity; even if networks may be traced back to the eighteenth century in both linguistics and biology. Today, models of reticulation are widely used in a variety of scientific fields on a formalized basis.

1 "The formation of different languages and of distinct species, and the proofs that both have been developed through a gradual process, are curiously parallel. … The survival or preservation of certain favoured words in the struggle for existence is natural selection" (Darwin 1882: 90).

In biology, research on prokaryote evolution indicates that lateral gene transfer is a major feature in the evolution of bacteria. In the field of linguistics, the mutual lexical and morphosyntactic borrowing between languages, as well as the wave-like distribution of innovations, seems to be much more central for language evolution, as the family tree model is likely to concede. In the humanities, networks are employed as an alternative to established phylogenetic models, to express the hybridisation of cultural phenomena, concepts or the social structure of science.

However, an interdisciplinary display of network analyses for evolutionary processes remains lacking. It is this gap we intend to fill with our book. The book is directed towards a wide readership, including biologists, who are interested in the methodological and theoretical reflections of evolution, linguists, who work on the development of languages, and historians of science, who examine the evolution of ideas. This book is based on an interdisciplinary conference and an interdisciplinary research project that were funded by the German Ministry of Education, and which focused on examining the concepts of evolutionary processes in different disciplines from a general perspective. However, these concepts were not regarded as completely homogeneous, but comparable according to similar relationship patterns. Therefore, this volume includes approaches studying the evolutionary dynamics of science, languages and genomes, all of which were based on methods incorporating network approaches.

We wish to thank all contributors, and hope to foster research in the direction of evolution that is understood as a network process in different fields of research.

The Editors, May 2013

REFERENCES

Brinkworth, M. & Weinert, F. (2012): Evolution 2.0. Implications of Darwinism in Philosophy and the Social and Natural Sciences (Berlin, Heidelberg: Springer).

Darwin, C. (1859): On the Origin of species by means of natural selection: or the preservation of favored races in the struggle for life (London: John Murray)

Darwin, C. (1882 [1871]): The Descent of Man and Selection in Relation to Sex, (2nd ed), (London: John Murray).

Dawkins, R. (1983): 'Universal Darwinism' in D.S Bendall (ed), Evolution from Molecules to Man (Cambridge, UK: Cambridge University Press): 403–425

Gontier, N., Van Bendegem, J.P. & Aerts, D. (eds) (2006): Evolutionary Epistemology, Language and Culture: a Non-Adaptationist Systems Theoretical Approach (Dordrecht: Springer).

Levit, G.S., Hossfeld, U. & Witt, U. (2011): 'Can Darwinism be "Generalized" and of what use would this be?', Journal of Evolutionary Econonomics 21:545–562.

Mesoudi, A. (2011): Cultural Evolution: How Darwinian Theory Can Explain Human Culture and Synthesize the Social Sciences (Chicago: Chicago University Press).

Ruse, M. (ed) (2012), The Cambridge encyclopedia of Darwin and evolutionary thought (Cambridge: Cambridge Univ. Press), 2012.

Schurz, G. (2011): Evolution in Natur und Kultur. Eine Einführung in die verallgemeinerte Evolutionstheorie (Heidelberg: Spektrum).

Sydow, M.v. (2012) From Darwinian metaphysics towards understanding the evolution of evolutionary mechanisms. A historical and philosophical analysis of gene-*Darwinism* and universal *Darwinism (*Göttingen: Universitätsverlag Göttingen).

1. NETWORKS AND EVOLUTION IN THE HISTORY OF SCIENCE

EVOLUTION OF KNOWLEDGE FROM A NETWORK PERSPECTIVE: RECOGNITION AS A SELECTIVE FACTOR IN THE HISTORY OF SCIENCE

Heiner Fangerau

"Darwinian" approaches to describe the development of knowledge gained wide public reception in the 1970s and 1980s, when several books about connections between biological evolution and the evolution of concepts in science were published and when corresponding ideas of leading authorities in biology and philosophy, like Konrad Lorenz or Karl Popper, were popularized.[1] In this context Donald T. Campbell (1974) coined the term "evolutionary epistemology" in an essay about Popper's theories of conceptual change to refer to this interdisciplinary endeavour to find generalising descriptions of knowledge development. He interpreted Popper's ideas in light of metaphors borrowed from evolutionary biology and argued convincingly that the development of scientific knowledge was the result of variation, trial and error, transmission, selection, and adaptation (Campbell 1974).

Of course, the basic conceptual link between epistemological considerations and the theory of evolution is much older and can be dated back at least to the 19th century (Richards 1987: 575), but Campbell's introduction of this term commenced a lasting debate about the strength and validity of analogising knowledge development and biology. It soon became clear that the meaning of "evolutionary epistemology" needed clarification, especially because Lorenz and Popper seemed to have addressed different spheres of interest when they replied to Campbell's ideas (Vollmer 1987). Lorenz addressed the "evolution of cognitive systems in general and of our cognitive abilities in particular" (Vollmer 1987: 203), whereas Popper discussed the evolution of scientific knowledge. He was interested in the philosophical and historical aspects of the development and fate of scientific knowledge, rather than in the biological foundations of the brain's cognitive functions. Following this direction, which has been thoroughly discussed by authors such as Stephen Toulmin (1972), Robert Richards (1987), and David Hull (2001 [1988]), the aim of

1 See for example Oeser (1988); Plotkin (1982); Popper (1979); Radnitzky and Bartley (1987); Reitmeyer and Marx (2010); Richards (1987); Riedl and Kaspar (1980); Vollmer (1975); Wuketits (1983). A dialogue touching the issue held by Lorenz and Popper in Altenburg in 1983 was published as a pocket book and sold in 6 editions with 36.000 copies until 1994 (Popper et al. 1985: 30–31). A review of the German discourse was published in the weekly newspaper "Die Zeit" in 1980 calling evolutionary epistemology the Copernican turn of our times (Zimmer 06.06.1980).

this paper is to add a network perspective to the evolutionary interpretation of the history of science.[2]

I will argue that knowledge development can be reconstructed and displayed as a networking process. In this approach networks are characterized by nodes representing entities like ideas or people, links symbolising horizontal and vertical relations between nodes and the absence of a clear staring point. With this approach, I take a path paved by authors such as Stephen Toulmin, Mary Hesse and Bruno Latour, who described different network perspectives on science and the scientific system around the time that evolutionary epistemology entered the scientific discourse.[3] Toulmin for example addressed "the rational enterprise of a natural science [...] as a changing population of scientists, linked together in more or less formally organized institutions" (Toulmin 1972: 262) and Hesse developed a network model which "interprets scientific theory in terms of a network of concepts related by laws, in which only pragmatic and relative distinctions can be made between the 'observable' and the 'theoretical'" (Hesse 1974: 4). On cognitive and social levels, network analyses can be used to reconstruct the evolution of scientific ideas as elements of scientific concepts. The actors responsible for the processes of selection and transfer constitute the organisational structure of such a network, in which knowledge is produced, retained, and transmitted through lateral and horizontal transfer. In analogy to biology, Hull called this formation the demic structure of science (Grantham 2000; Hull 2001 [1988]). Thus, I follow the suggestion that the evolution of knowledge as a social product can be better described and examined using the "network" metaphor than with the classical tree-like model of vertical transgenerational transfer borrowed from classical biological concepts of evolution.[4] In this approach, "selection" may be viewed as the evolutionary element – certain replicators (ideas, approaches, theories) that fit the environment (the rationality and motivation of interactors) are chosen from a variety of possibilities – and the network can be viewed as a representation format for the reconstruction of lateral transfer in the histories of medicine and biology.

I will also argue – based on a historical example – that the processes of selection and transfer, which occur in current biological and medical research, are partly the result of researchers' personal motivations to gain recognition for their scientific work within a network of scientists.[5] Additionally, the issue of which researcher other scientists believe in a controversial situation depends to a certain extent on whom they trust for any reason. Thus, I suggest that "recognition" and related "self-

2 In his proposal of "A neo-Darwinian model of science", Knudsen (2003) provided an excellent short overview of the differences and commonalities among these authors.
For an overview of Evolutionary Epistemology see also the essay collection by Radnitzky and Bartley (1987), which also includes essays by Popper, Campbell and Vollmer.

3 See, for example, Hesse (1974), Latour (2005). For a precise and concise overview, see Dear (2012: 46–50).

4 Molecular evolutionists have argued that the network approach is superior for the description of biological evolution because it enables, for example, the characterisation of processes of lateral gene transfer. For an overview, see Martin (2011).

5 Some of my thoughts on recognition in science presented here and in the following have been recently published also in German (Krischel, Halling, Fangerau 2012).

constitution" are driving forces in the evolution of knowledge in networks. These factors can be seen as crucial elements of selection and transfer when these processes are understood as being organised within a social structure of science.

After a very brief overview of the key features and limits of an evolutionary epistemology I propose the use of a network approach to map the evolution of ideas: connections among scientists are described as representations of the replication of ideas, the diachronic perspective on these connections helps to characterise knowledge evolution as a networking process. Following these theoretical considerations based on the existing literature, I use the example of the physiologist Jacques Loeb's views on citation around 1900 to describe how scientists' desire for recognition drives the selection and transfer of scientific ideas. By connecting this empirical example to the previous considerations, I finally take up the idea that recognition and self-constitution are important driving forces in networking processes in science and argue that they foster the evolution of knowledge.

EVOLUTIONARY EPISTEMOLOGY

Some factors support the belief that the historical aspects of the development of ideas can indeed be understood in evolutionary terms. Most systems evolve (Vollmer 1987: 212), and several metaphors from biology can be transferred readily to the description of knowledge development. Above all, scientists' selection of ideas, theories, and/or concepts and their transfer to others, sometimes transgenerationally, is a central element of the system of science. Variations and transformations of ideas occur and the recombination of ideas generates new concepts. Hypotheses can be seen as replicators during this process (Popper 1979), and the scientists involved as interactors (Hull 2001 [1988]). In concordance with the topos of the "survival of the fittest", realists or empiricists have suggested that theories fitting reality best or according with empirical observations "survive" selection and are transferred (Collin 2003). Similarly, Niklas Luhmann (1998: 546–56) viewed the evolutionary selection of ideas as resting on criteria of plausibility or self-evidence, but, in contrast to the realists, he pointed out the historical contingency of what is considered to be plausible.

Nevertheless, many authors have cautioned that efforts to equate organic evolution with the development of science as a system in general and the evolution of scientific knowledge in particular may be too hasty. Above all, selection processes in biology and the system of science differ. For example, Vollmer (1987: 214) warned against equating fitness, the evolutionary criterion for success, with the "truth" of scientific knowledge because "fitness may be provided by quite limited or even deceptive cognitive means". Additionally, human influence on science is much greater than on natural (not breeding) biological selection processes, and scientists' motivations must be taken into account.[6] Finally, the evolution of ideas seems to be more goal oriented (explaining phenomena on the basis of rationality

6 This argument can be traced back to the psychological theory of Adam Smith (Loasby 2002).

and defined methodology) than undirected biological evolution, which is comparable to trial and error (Sterelny 1994). As Paul Thagard (1980: 193) pointed out when referring to the evolution of knowledge,

> "Variation is not blind […] it is not wholly […] determined by context either. There is a subjective, psychological element in discovery along with an aim-oriented, methodological element. Hence we are not in a position to borrow a model for the growth of knowledge from Lamarck, Hegel, or Darwin."

He stated that publication and pedagogy, rather than a process similar to biological inheritance, were the forces driving the transmission and preservation of knowledge (Thagard 1980: 192). He urged the development of a model that included

> "1. the intentional, abductive activity of scientists in initially arriving at new theories and concepts; 2. the selection of theories according to criteria which reflect general aims; 3. the achievement of progress by sustained application of criteria; and 4. the rapid transmission of selected theories in highly organized scientific communities" (Thagard 1980: 193).

Following this stream of thought, it might be argued from a historical standpoint for an evolutionary epistemology that focuses on "selection" and "transfer" as crucial elements in the development of knowledge.[7] That said, I do not discard analogies between biological evolution and the evolution of science, but suggest retaining them on the broad level of the metaphorical explanation of mechanisms that work in systems. I am aware that I take an explicitly "externalist" perspective with this suggestion, as I do not examine theories or hypotheses alone, although they are substantial elements of scientific endeavours. Rather, the relational and social aspects of the methodologically guided production of knowledge are focussed here. With this emphasis, it is not intended to argue against realists' claims that scientific knowledge has a counterpart in the real world or that scientists are working to find the "truth" (Churchland and Hooker 1985). Rather, I propose concentrationg on the networks of the producers of this knowledge and the social mechanisms of selecting and transferring special representations of viewing the phenomena of the world.

MAPPING THE EVOLUTION OF CONCEPTS: A NETWORK APPROACH

Above all, a network is a graphical representation of relationships, "a collection of points joined together in pairs by lines" (Newman 2010: 1). It consists of nodes (or vertices) representing elements that are linked and links (or edges) representing different forms of connection. The whole system of nodes and links is called a graph. Links between nodes can have different strengths and nodes can be closely related *via* other nodes without being linked directly. Thus, a network is an overarching description of connected elements, or, as Easley and Kleinberg (2010: 1) described it, "a pattern of interconnections among a set of things". This description captures the semantic connotation of the term "network" more than the pure graphical de-

7 Selection and transfer, or transmission, are linked, as suggested by Knudsen's (2003: 103) definition of the "[…] selection of explicit scientific knowledge as the gradual and slow change in the distribution of scientific ideas caused by their differential social transmission".

scription. Network analyses have a long tradition in sociology, where they have been used to describe the structures of social relations and the regularities between certain relational structures and various kinds of social interaction or effect, such as the exertion of power or economic success (Freeman 2004). However, network models can be adapted to "data that do not reflect concrete social relations but rather relations among concepts or discursive elements" (Gould 2003: 242), as in historical research. In both senses, the network model is a useful tool for the description of connectedness within the context of an evolutionary view of knowledge development. The network is not a physical structural pathway for ideas pre-structured by a substantial element determining the fate of knowledge, but is as real as a map. It is an abstract representation of the selection and transfer of ideas.

In *Science as a Process*, Hull (2001 [1988]: 434) listed several qualities of the selection and transfer of ideas in scientific systems that can be interpreted readily as characteristics of a network as the structural pathway for the evolution of knowledge, with scientists serving as the "vehicles" for knowledge elements ("replicators"). Firstly, nodes and links may be appropriate representations of the idea that "progress in science occurs by means of recombinations" (Hull 2001 [1988]: 434) of existing ideas. The recombination of ideas in a network is symbolised by nodes representing ideas or scientists (as vehicles of ideas), and links representing the selection of combination of ideas carried by the vehicles. Secondly, a network representation allows for the symbolisation of "cross-lineage borrowing" of ideas (Hull 2001 [1988]: 450). An innovation may have multiple origins and can be transferred horizontally and vertically, which can be better represented in a network than, for example, in a bifurcating depiction of knowledge development. Thirdly, the conceptual kinship (Hull 2001 [1988]: 435) of different ideas can be displayed in a network. Common links can be used to symbolise scientists (as vehicles of ideas) who share ideas or elements of concepts with identical descent. Finally, different combinations of ideas resulting in the evolution of knowledge are the results of selection processes, which can be described suitably by a network. If selection (e.g. of ideas that are transmitted) is seen as an "interplay between replication and interaction" (Hull 2001 [1988]: 436 f.), links between nodes symbolise positive selection and the exclusion of certain nodes in a diachronic perspective represents negative selection.

In the evolution of science, the exchange of ideas between network clusters perceived as, for example, "disciplines", and the recombination of these ideas may be hypothesised to lead to what is perceived as scientific progress. Although evolution is by definition undirected, supposed progress may be the result of the selection of the fittest concepts from diverse ideas. In other words, the borrowing of ideas from other disciplines leads to greater diversity, which improves the chances of finding a fit concept. Some findings of the network theory established in sociology relate extremely well to theories of innovations in science and technology. For example, Mark Granovetter's "strength of weak ties" hypothesis highlights that a small number of nodes in some network structures may have few links, but that these links may serve as bridges between clusters. Thus, these nodes are valuable elements because they link network clusters to one another, allowing for information exchange between clusters that would not have had contact without the respective nodes.[8] They serve as so-called "brokers", an intuitively understandable description of nodes representing social actors or elements of ideas. Several network analyses (with emphases on economics) have described "the diffusion of innovations" as such a networking process (Easley and Kleinberg 2010: 498).[9] At the same time, however, a highly interconnected idea might have a "selection advantage" because it is less susceptible to isolation following ruptures of connections. Other links can take up the roles of broken, deleted, or partitioned connections. Bearman et al. (2002: 66) have emphasised this point convincingly in arguing that even events reconstructed by an historian can be displayed in a network structure, because only connected events result in a meaningful historical event sequence. If the deletion of a link results in partition, the respective event might be interpreted as pure coincidence. Transferring this concept to networks of ideas would mean that ideas with very few links to other ideas might be forgotten quickly.

To describe the connectedness of ideas, the common descent of a thought from one origin and the selection of ideas from a diverse set, the deconstruction of broad scientific concepts into their elements is necessary, just as the identification of genes constituting a phenotype is necessary for the reconstruction of biological relations. One way of abstracting individual elements from a scientific concept is to apply frame theory, an approach borrowed from the cognitive sciences. Andersen, Barker, and Chen (2006) showed convincingly that this theory is a powerful tool for the dissection of concepts and analysis of the fate of their elements from a diachronic perspective. They focused on "The Cognitive Structure of Scientific Revolutions" in anatomising concepts to analyse, for example, Thomas Kuhn's concept of incommensurability. Inherent in this approach is also a very feasible method to describe the evolution of knowledge in the form of interconnected elements of ideas (i.e. Hull's replicators). The underlying idea of this approach is that semantic (also known as conceptual) knowledge forms a central basis for the use of language to describe solid facts and abstract terms (Klein 1999).[10] An essential aspect of semantic knowledge is the ability to categorise. Early cognitive-scientific approaches addressing the categorical structuring of semantic content used feature lists, which enable the definition of a distinct term by compiling its characteristic features (Rosch et al. 1976). These models were unidimensional and lacked flexibility, in contrast to approaches using frames that originated from a systematically networked structure of object / concept characteristics. Frames focus on the hierarchical order of characteristics that define a certain term (Barsalou 1992).[11] They are stereotypical and empirically founded structural formats for various forms and fields of

8 On Granovetter's hypothesis from the 1960s and further centrality measures in network analyses, see Easley and Kleinberg (2010: 43–47).

9 Coleman et al. (1957) published a path-breaking yet classical study using this approach. Collaboration networks in science have also been examined using citation analyses; see among others Bordons and Gómez (2000).

10 The following ideas have been outlined previously in German in Fangerau et al. (2009).

11 Marvin Minsky introduced the term "frame" in artificial intelligence research in his seminal study "A framework for representing knowledge" (1974). See also Minsky (1990).

knowledge (Minsky 1985: 244). As an entity, each frame is comparable to a concept. Conceptual knowledge is represented by the combination (and, from an evolutionary perspective, recombination) of information elements.[12]

A frame describes an object on the basis of general *attributes* to which specific *values* can be assigned (Barsalou 1992: 29–44). For example, numerous attributes can be assigned to the medical diagnostic concept of diabetes, such as the amount, colour, and taste of urine. Certain values are assigned to these attributes, according to an actual urine type (e.g. polyuria, oliguria, anuria; light, dark, sweet, salty). These values are subordinated to the attributes and represent a possibility within the attribute-value set. As such, they can form additional frames (e.g. sweet as a type of taste) or belong to higher-order frames (e.g. diabetes as a kind of disorder represented in urine). Frame analysis, understood as a diachronic network analysis of nodes and links representing elements of ideas and their transmission, enables the assignment of attributes and values in the course of temporal changes and thus describes phases of transition from one concept to another. The combination, selection, transfer, and recombination of elements of concepts to new concepts can be described in the form of interlinked attribute-value sets. Retrospectively, a researcher can determine whether transfer led to successful (fit) or unsuccessful recombinations, and whether selection blocked insight (e.g. by linguistic incompatibility), promoted it (e.g. by epistemologically sharper terminology), or even enabled new scientific approaches. Basically, logical breaks and inconsistencies in attribute-value constellations, which are the result of new empirical findings or reconfigurations of idea elements, result in conceptual shifts and, thus, evolution of knowledge.[13] The trans-temporal interconnections between attributes and values of concepts that stand for successful recombinations ultimately characterise a conceptual change, or what is seen as "progress".

However, one should not forget that the resulting structure of relationships among elements of ideas is a function of the underlying selection and transfer processes, not of their origin.[14] People, i.e. scientists, decide, which ideas or elements thereof they want to include in their network of ideas and which they want to discard. Hull sees scientists as "essential links in conceptual replication systems" (Hull 2001 [1988]: 447), who expect explicit or implicit credit for ideas or their transfer. They accept and select ideas for replication that they recognise as valuable or reasonable to be transferred. This social element of the system of science can also be depicted in networks. In a description of scientific development as a collective action, the abstract idea of a network to describe the evolution of knowledge becomes very concrete at this point.

12 In cognitivism, concepts, although universally determined, are understood as individual mental units (Strauß 1996: 42). I thank Michael Martin for raising this point and referring me to the relevant literature.

13 Andersen, Barker, and Chen (2006) have shown that frames can be used productively for the analysis of thought-style shifts on a conceptual level. They pointed to hierarchical fractures in frames through the introduction of novel attributes, values, or constraints that force a conceptual reorientation.

14 Gould (2003: 261) made a similar comment on other network data.

MAPPING THE SOCIAL STRUCTURE OF SCIENCE: NETWORKS OF SELECTION AND TRANSMISSION[15]

In the history of science, so-called social constructivist theories have been used to interpret apparently objective scientific facts as products of the social conditions of research contexts. From this perspective, the production of knowledge gains the status of science as an organised practice only if not only individuals, but also collectives, believe in the prevalent methods of knowledge production and in the resulting scientific products (i.e. hypotheses, ideas, descriptions, new practices).[16] This social view of the establishment, implementation, and perpetuation of scientific theories, proposed by authors such as Kuhn (1962) in his path-breaking work on the structure of scientific revolutions and Latour (2005) in his far-reaching presentation of the actor-network approach, had already been put forward by Ludwik Fleck in the 1930s. Fleck (1979) described the "Genesis and development of a scientific fact" as a collective process and presented a model of how interactions among researchers, who form a thought collective, foster the creation of facts through negotiations of methods, hypotheses, and the validity of theories. With reference to Hans Vaihinger's "philosophy of 'as if'" (1924), the philosopher Arnold Kowaleski (1986 [1932]) proposed that scientific reasoning and the production of knowledge purposefully lead to fictions that are necessary for further development of the respective knowledge or useful on a practical (and methodological) level. In Kowalewski's view, in an environment of equally correct and/or acceptable fictions, only the collective recognition of certain fictions in a "community of ideas" ("*Ideengemeinschaft*") would lead to their implementation (Kowalewski 1986 [1932]). From an evolutionary standpoint, Kowalewski's ideas can be interpreted as proposing that ideas are selected and subsequently transferred in collective (networking) actions.

Reconstructing the processes of idea selection and transfer on the level of the scientific literature has a long tradition as bibliometrics in the information sciences.[17] In citation and/or co-citation analyses, articles published by authors serve as surrogate parameters for the ideas represented therein and for the authors as bearers of these ideas. Publications serve as an important substratum of accepted knowledge that is to be transferred. Citing and being cited in publications can be interpreted as recognising or being recognised as the result of a selection process. A network can be constructed through the examination of citations of authors in a corpus of literature and can be perceived as a snapshot of knowledge selection. By adding a temporal level, the transfer of selected elements can be represented, aiding the visualisation of an evolutionary process. Citations (as surrogate parameters for scientists and their ideas) that crosslink texts can be considered to represent an intellectual network and a symbolic social network constructed strategically by au-

15 Some of the following thoughts have been published elsewhere with a different focus in German (Fangerau 2009a; Fangerau 2010b).

16 Jan Golinski (2005) has provided a summary account of these views.

17 For an overview, see the contributions published in a festschrift for Eugene Garfield (Cronin and Atkins 2000).