"A picture speaks a thousand words." This old Chinese proverb is a perfect description of the work of **Lothar Krempel** *from the* **Max Planck Institute for the Study of Societies** *in Cologne. The scientist transforms dreary data into fascinating graphics. Whether international trade relations or the interrelationships between Germany's biggest corporations – his images illustrate how complex social networks operate and how they change over time.*

Thinking with Your Eyes

At first glance, the diagram looks like the map of a rather strange subway network. But the stations are not travel destinations, but the names of well-known companies. Upon closer look, the colored arrows and circles form an impressive network between Germany's largest firms, known collectively as Deutschland AG. Like a road map, the plan depicts the financial ties that link the one hundred leading banks and financial and industrial corporations in Germany. It makes the connections between them palpable, something which is otherwise impossible to achieve with endless columns of statistics.

Just how clearly these graphics communicate becomes obvious when this picture is compared with another: whereas the first provides a snapshot of the heart and soul of free enterprise in Germany in 1996, the second depicts the situation four years later. And it quickly becomes apparent that the network of Deutschland AG is gradually dissolving. Although the business press has been hinting at this erosion for years, it is the stark contrast between these diagrams that makes it possible even for lay people without a lot of background knowledge to understand exactly what is happening.

Between 1996 and 2000, the names of many of the players changed, some left the scene, and new companies appeared. The key information, though, is the disappearance of a large number of the main connecting arrows – combined with the breakup of smaller subcenters in the network. The web of mutual financial ties has become much less intricate, much looser; and toward the edges of the picture it dissolves completely. Two visual aids are all it takes to translate the incredible dynamism of the German economy's ongoing transformation into a universal language.

"The remarkable thing is that my kids can understand pictures like these," says the man who created them. "The better they are, the fewer words you need to explain them." Lothar Krempel is a scientist at the Max Planck Institute for the Study of Societies in Cologne. He researches how networks in societies function: the analysis of social networks is his field of expertise. In his work he purposefully relies on our eyes' ability to process many different pieces of complex information at the same time.

Simple Clarity Replaces Columns of Data

These diagrams cannot help but call to mind the ancient Chinese adage that a picture speaks a thousand words. The Chinese were well aware that we think primarily in images. Lothar Krempel's diagrams of the company network in Germany prove how effectively this trait can be used to illustrate scientific findings. The graphics are based on statistics published every two years by the Ger-

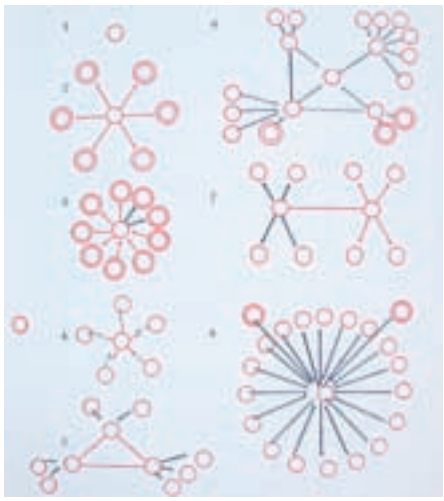
Photo: Zefa

man government's monopolies commission. The tables contain all the key information on the mutual connections between German companies. But the abstract columns of data do not allow the interesting links and developments to shine through. Even experts have to look at the figures long and hard to get an idea of what the network is really like. This understanding is just what the pictures created in Cologne provide – remarkably fast and intuitively. Their simple clarity can be deceiving and almost masks the amount of time and effort that went into producing them.

Network visualization is the name of the sophisticated methodology Lothar Krempel uses to bring his research objects to life. These objects can be corporate networks, global trade relations between nations, written correspondence between famous scientists, or even the international market for professional soccer players or cars. With every new research object, the researcher asks himself the key question of how to map out the complex network in a way that makes its main characteristics easily visible.

For Lothar Krempel, the focus is not just on the intuitive clarity of what he produces. His diagrams are first and foremost serious visual aids, intended to give researchers and experts who work with networks in the worlds of politics, public administration or business a set of scientifically proven findings to draw on. They therefore must translate the precise, statistical data into a visual language that can be read and interpreted with equal precision.

When the Max Planck researcher describes how data is translated into images, his words take us on a journey through a wide variety of disciplines. Naturally, computers play a key role: it was not until their computing power exploded in the 1990s that the mathematical processes gained the necessary potential. "Massive optimization algorithms are at work in the background, first putting the data in order," explains Krempel. The computer sorts all the data in whatever way it was programmed. Krempel extracts the computations he needs, known as algo-



The early days of network visualization: Hand-drawn sketch of typical group relationships by psychotherapist Jacob Levy Moreno in 1953.

Illustration: Moreno, Jacob L., Who Shall Survive? Foundations of Sociometry, Group Psychotherapy and Psychodrama, Beacon House, 1953

rithms, from fields such as physics – and electrical engineering: similar processes are used there to calculate the optimal positioning of electrical circuits on chips and boards to avoid unnecessary overlaps.

Once the computer has finished its highly efficient work in the data mine, it has produced the raw material for a diagram. Even at this stage, a plan can be drawn outlining the positions of the players in relation to each other and the connections between them. Then follows the fine-tuning, during which the researcher considers what additional information he wants to incorporate in the chart. In the Deutschland AG diagrams, for example, the size of the circles indicates the size of the stake a player has in other players in the German company network. And the color specifies whether a given player is one of a financial or industrial corporation's subsidiaries.

This kind of supplementary information must also be clearly legible; it must not confuse the viewer. That is why Krempel looked into disciplines that have already developed highly efficient methods of turning abstract data into easily understandable symbols, signs and colors: the fields of cartography, colorimetry and informational graphics. Cartographers in particular have centuries of experience in how our eyes take in information. Their empirically determined mapping standards reflect the way in which our visual perception is able to optimally process color, form and movement.

GRAPHIC: MORENO, JACOB L., WHO SHALL SURVIVE? FOUNDATIONS OF SOCIOMETRY, GROUP PSYCHOTHERAPY AND PSYCHODRAMA, BEACON HOUSE, 1953

A citizen's social network as depicted by Thomas B. Lemann and Richard L. Solomon in 1952.

CLOSE CONTACT WITH THE ART SCENE

"Basically, everything we use here has already been thought of somewhere," says Krempel, "but we need to find out where that experience exists and bring it all together." The social scientist not only had to search out the knowledge, he also had to learn the specialist language used in each of the disciplines. Only when he had dedicated enough time and effort to this background work could he unlock the knowledge he needed to develop his talking pictures.

"The first subject I tackled was global trade relations," recalls Krempel, laying a diagram on the table. The web of finely intertwined lines illustrates the trade flows between the member states of the OECD, the Organization for Economic Cooperation and Development, in 1992. It was produced on the basis of official data from the organization. "This one's a classic," he says. The picture now even hangs in the New York Hall of Science – and provides magnificent proof that science doesn't have to be dull. "It can also be beautiful, aesthetic," Krempel points out. So it comes as no surprise that the researcher maintains close contact with the art scene and took part in the Ars Electronica festival in Linz. In the fall of 2004, this internationally renowned event was dedicated to the language of networks from the perspective of art and research. But what does the word "network" really mean to a scientist?

"Analyzing a network is based on observing relations, and I can use what I discover to put together a system," explains Lothar Krempel. The mutual relationships between the players in a network form the underlying web that holds it all together. "These relations have long been the subject of statistical multivariate analysis: multidimensional scaling, factor analysis, correspondence analysis and so on," says Krempel.

Of course, the modern social sciences, just like the natural sciences, rely heavily on mathematics to extract their research findings from large volumes of raw data. But in bringing up all those statistical analyses, the Max Planck scientist from Cologne simply wants to point out a key question – one that is easy to understand without mathematics, namely: How can all those mathematical formulae be manipulated such that they result in easily readable diagrams of networks?

A naive, direct translation of the figures into a standard system of coordinates often produces something that is utterly indecipherable. "Out of the relations, distances are produced in an abstract setting, and these distances can be very great indeed," explains Krempel. "You can roughly compare it with maps of subway networks: they don't show the geographical aspect; they shrink everything so that each station is the same distance away from the next."

This abstraction makes subway maps easier for our brains to take in. Even though they are spatially distorted, we can remember the details easily and this knowledge gives us a means of orientation. Their secret is that they "bend" the geographical

truth while still keeping the stations in the right relation to one another. This is the rule that the makers of the maps must stick to. "The remarkable thing is that the human eye is very good at reading these kinds of relations," says Lothar Krempel. For him, this means he can afford to change the distances between the objects in his diagrams – by pulling clusters apart, for example, to make them legible.

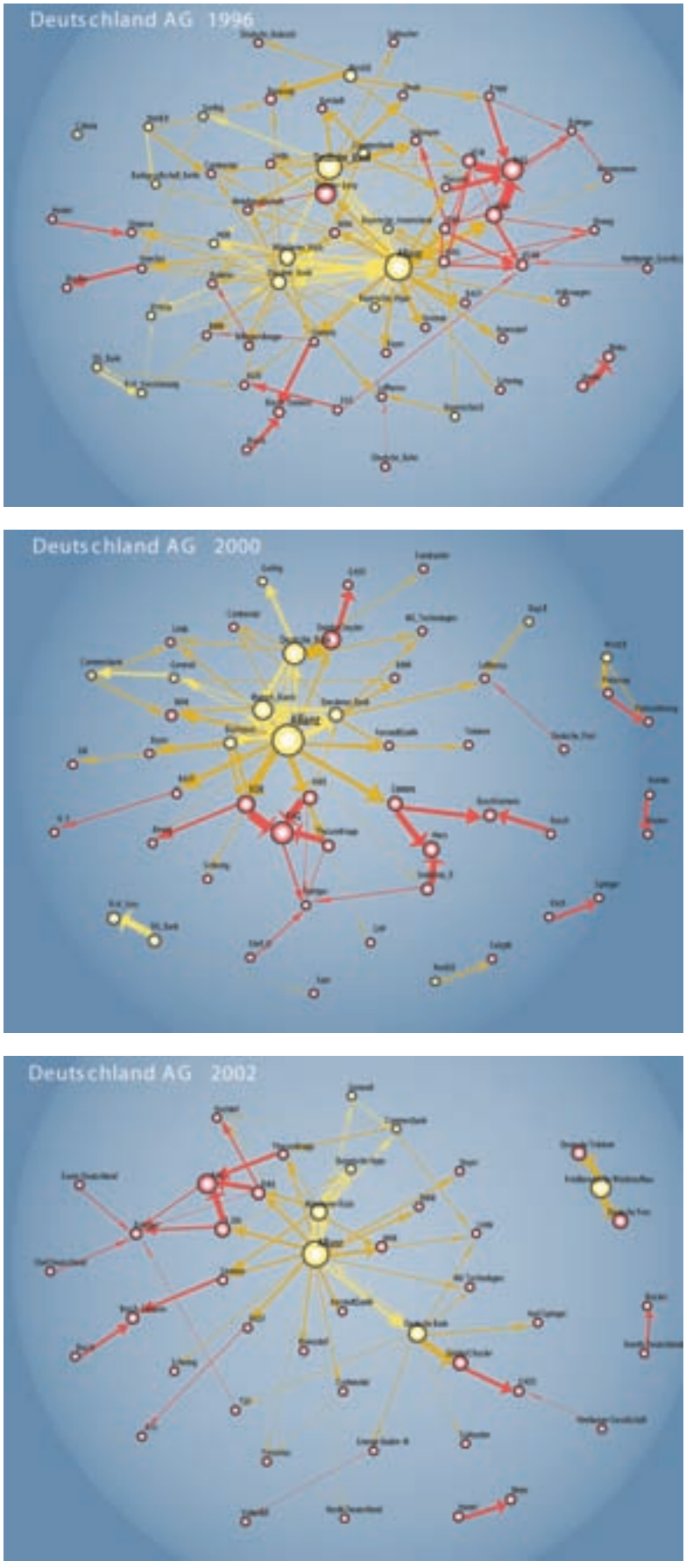
But the neighborhoods between the entities are sacred; they must be preserved in the diagrams. This is when the characteristic features of the networks he maps out become immediately apparent.

"The first step is always to ask yourself how you can put the information in some sort of order," reveals Krempel on the subject of how he analyzes his data. With a network as historically complex as that between Germany's biggest corporations, there are many possible ways of ordering, analyzing and mapping the data (MaxPlanckResearch 2/2003, p. 72). After all, it reflects more than a hundred years of German history, from Bismarck to the present day. Martin Höpner, who also works at the Max Planck Institute in Cologne, researched this history from a scientific viewpoint.

The Long History of Deutschland AG

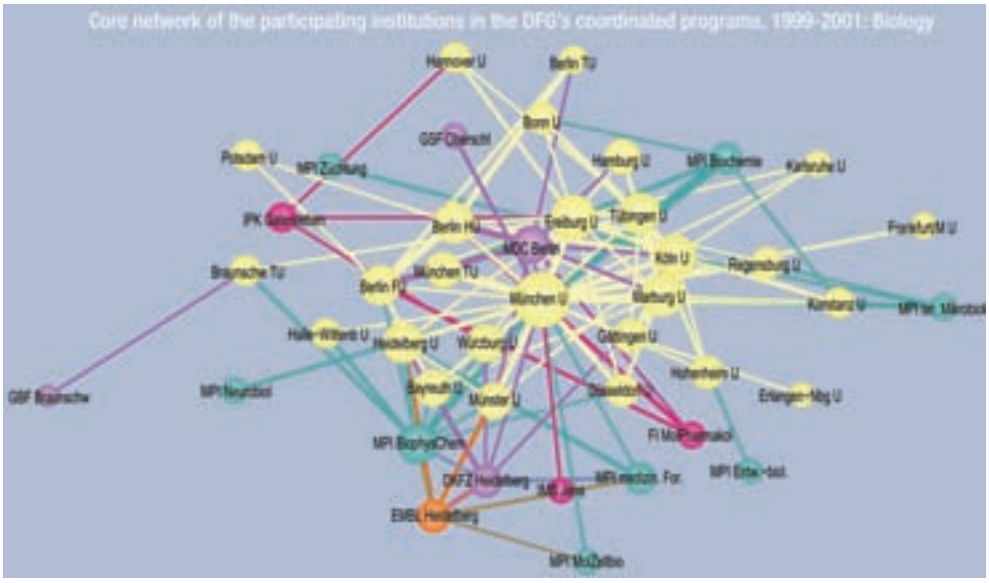
In order to map the historical development of Deutschland AG, the two researchers combined two methods of depiction: Höpner's text tells the story and backs it up with data and facts, while Krempel visualizes the past years' developments in his pictures. This dual approach brings the history of this unique business network to life.

The nucleus of Deutschland AG grew out of the period of rapid industrial expansion in Germany in the late 19th century, known as the



The interconnections between Germany's one hundred biggest corporations in 1996, 2000 and 2002. Financial institutes are depicted in yellow, industrial corporations are red, and companies that are a mix of both are orange. The series of diagrams dramatically illustrates how the Deutschland AG network has eroded over time.

Graphic: MPI for the Study of Societies/Lothar Krempel



Graphic: MPI for the Study of Societies/Lothar Krempel

The research network supported by the German Research Foundation (DFG) in the field of biology. The universities (yellow) also cooperate with non-university research institutes, and ties with the Max Planck Institutes (green) are particularly strong.

Gründerzeit. Numerous young companies were faced with a crisis between 1873 and 1879 because they did not have the capital to continue on a growth path. Yet, without growth, they would not survive. This led to an economic crisis, an idea with which we are familiar today but which was a completely new concept in those days. Germany's startled politicians made the country's leading banks take on the obligation: together they were to provide the life-saving cash transfusions that industry needed, and the companies were to pay back the loans primarily in the form of stocks and shares.

Thus arose a complicated network of mutual financial ties, at the center of which lay the big banks and financial institutions. The economic crisis of the 1920s subsequently served to strengthen this quasi-cartel: the companies moved even closer together, resulting in the 1925 formation of the powerful IG Farben conglomerate, for example. In the Third Reich, the Nazis allowed the network to operate largely untouched because they needed it to enable the country to rearm and go to war.

Deutschland AG experienced its second major phase of economic growth in the 1950s – but now in the Federal Republic of Germany. The Allies may have broken up the big cartels like IG Farben, but they did not strip the companies of their assets in the Western sectors. The network again played an important role in the West in the period of reconstruction of the early postwar years, which was largely based on the principles of planned economy.

In the mid-1960s, West Germany gradually changed its economic policy. New laws progressively called for more transparency in the network. In the 1970s, Deutschland AG saw the first signs of approaching globalization: rich oil sheiks started to show more of an interest in buying up shares in German companies. Deutschland AG gradually began to erode. But it wasn't until the mid-1990s that the process really picked up momentum. The increasingly globalized economy offered industrial corporations new opportunities, but it also put them at the mercy of global market forces more than ever before. And this meant that the banks became less and less interested in investing in industrial corporations. While the business system was still very nationally oriented, they had been able to keep an efficient check on the safety of their investments through the system of supervisory board monitoring. Globalization took away this security.

Hostile Takeovers Turn Lucrative

Moreover, the banks were faced with new conflicts of interest. Investment banking was becoming more and more lucrative – and with it the arrangement of hostile takeovers. This happened to Deutsche Bank in 1997, for example, when it was involved in organizing Krupp's hostile takeover of Thyssen, even though it had a representative on the supervisory board at Thyssen. The bank has been consistently extricating itself from its financial ties in industry ever since. Even Chancellor Schröder's government is encouraging the further disintegration of Deutschland AG: the major tax reform of 2000/2001 made the sale of large share packages free from tax – a move that helped accelerate the dissolution of mutual financial relations.

"We now have a diagram of the situation in 2002, and you can see that the process of disintegration is continuing," says Krempel. He points out the red conglomerate at the top right of the 1996 picture, commenting, "Here we have a sector of industry that is dominated by interlocking interests: the energy sector surrounding the Ruhrkohle AG corporation." Indeed, RAG sits at the center of a complex labyrinth of relationships with many big power companies. In the network map from the year 2000, though, the web in the energy sector is much less complicated, with its midpoint having moved down below the main

hub around the firm Allianz. There we find a new big name: e.on. "A process of Europeanization is what's behind this," says Lothar Krempel, going on to explain, "Having merged into e.on, companies like Veba are now trying to establish a significant position in the European market."

The example of Deutschland AG shows that the two methods employed by the Cologne-based scientists together result in a clear yet multifaceted analysis. For the purposes of depicting the actual history, words are the best medium, which is why text is also of key importance to social scientists. The visualization of the network, on the other hand, shows in detail the changes that have occurred among the players and in their relations with each other. Thus emerges an overall picture that is both easy to grasp and very precise. Yet the use of images represents a minor revolution in the social sciences.

"In the humanities, people treat images with polite reserve," says Krempel, "because an image can have a very dubious function." Given that images have a very strong impact on us, it is also easy to manipulate using them. Advertisers try this on us on a daily basis, but it is the subtler tricks that are more dangerous. For instance, everyone is familiar with the colorful graphics that claim to prove the existence of a trend by inflating a tiny statistical blip to enormous proportions.

Scholarly mistrust of the image does have historical and philosophical roots, though, as Krempel explains. "It has partly to do with the Renaissance," he says. At that time, producing an image was a time-consuming and expensive task that had to be done by hand and that only the rich and powerful could afford. They often used pictures as a means of manipulation. For instance, proud portraits with all the insignia of power were intended to impress those who saw them and keep them submissive.

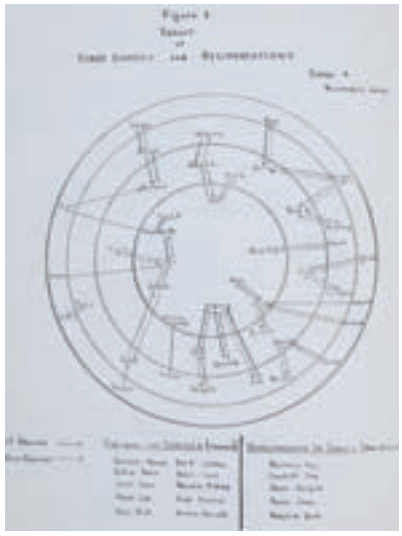
No wonder, then, that philosophers and thinkers were suspicious of the deceptive power of images. Even in ancient times, Plato objected strongly to painting, describing it as nothing more than imitation and phantasmagoria. This is the long and difficult relationship with imagery that has given scholars their critical view, says Krempel, explaining, "If you're looking for underlying truths, you need to get away from the immediate sensory perceptions – images are too powerful." That is why only a few research disciplines have traditionally developed a language of imagery, one of them being the field of biology. Their copperplate engravings were an important means of categorizing the typical features of plant and animal species.

Visualizations as Scientific Method

"If you want to use images in a scientific context, you need to specify very precise reasons why you used the methods you chose," stresses the Max Planck researcher. "You need to ensure that an image will not render more to its viewers than the underlying information." This is one of the strong demands he needs to fulfill in order to have his visualizations recognized as a scientific method. The reaction of colleagues in his field was inevitably cool at first. "Many of them said, 'Oh, he's drawing pictures,'" remembers Krempel with a smile. "After all, you can't tell by looking at pictures how much hard work went into them. That's something they can't tell you." However, the scientist has a weighty argument on his side: other disciplines have long since started applying these kinds of visualization methods with considerable success.

In order for his methods to be scientifically recognized, the researcher at the Cologne institute has to be able to give very precise reasons as to why and how he uses symbols and colors. To do this, he needs rules to define the human perception of sizes and colors. How that works is described by the so-called psycho-

Graphic: Moreno, Jacob L., Who Shall Survive? Foundations of Sociometry, Group Psychotherapy and Psychodrama, Beacon House, 1953



Graphic: Mary L. Northway, Ester B. Frankel, Reva Potershin (eds.), Personality and Sociometric Status, Beacon House, 1947

Who wants to sit next to whom? Depiction of preferences expressed by schoolchildren (top); the graphic below shows the friendships in a class setting.

Lothar Krempel with his picture that hangs in the New York Hall of Science. It illustrates the trade flows between OECD states in 1992.

metric functions. As Krempel explains, "Our perception of size, for example, or the perception of a circle to be double the size of another, is a subject that was examined over a hundred years ago."

More difficult to measure on a precise scale is how we perceive colors. "But colormetricians have been investigating color and color systems since about 1920," Krempel points out. In the process, they developed psychometric color terms in which the gradation of brightness and saturation gives rise to a precisely definable sensory perception. Krempel refers to this as sensory metrics. "It took me a year to understand exactly how colormetricians do it," he recalls. "And of course it is only a model, but it does describe how the perception of 90 percent of the population works."

Put simply, the psychometric color terms represent a kind of ruler – albeit one with a pretty complex scale. They can be used to measure human color perception in a precise manner. "These colorimetric models have been the international standard since 1976 and now play an active part in shaping our world," says the Max Planck scientist, adding, "the entire principle of digital photography is based on them."

So when Lothar Krempel applies his knowledge in the right way, the understanding of his graphics is not just intuitive: how people read the information is also subject to measurable criteria. "On the other hand, if you change the diagrams even slightly, they cease talking to you – they turn into puzzles," he says. "That is what happens if you don't use natural organization." When Krempel succeeds in creating good pictorial representations, they directly visualize the characteristics of the networks they depict. "These are preattentive processes that happen really fast and automatically."

Here, preattentive means subconscious: our eyes preprocess the images to an incredible degree without us even noticing. Krempel's visualizations purposefully make use of the fact that we are experts at recognizing objects and their relationships to one another. This is also what enables us to quickly get a sense of orientation in our surroundings.

The graphics produced in Cologne work as if, when looked at, a part of the cognitive process is happening outside the head – on paper, so to speak. "This is relatively new in the world of scientific visualization. Psychologists call it externalized thinking," explains Krempel. Put simply, computers take over the hard part of the thinking process for us: they preprocess the vast quantities of data, insofar as intelligently designed mathematical instruments can do so in an automated manner. The result allows viewers to interact with the data immediately and creatively – to analyze it, interpret it and translate it into models and hypotheses. Without this assistance, people would have to get their heads around the masses of data before they could even make a start. "This thinking now takes place outside of the head," says Krempel, explaining the effect of his diagrams. They therefore allow people to take an intelligent shortcut and move straight to the creative process.

How well this works is demonstrated by the visualization of a network that is vital to research in Germany: the German Research Foundation (known by its German abbreviation DFG) currently supports some 20,000 university research projects with funding to the tune of around 1.3 billion euros a year. For the DFG, it is, of course, interesting to see how this support impacts the way research institutes work together. For example, different working groups are able to use their funding to buy expensive equipment that other groups may not have, and then share the benefits with them. Such cooperation gives institutes the chance to make optimal use of financial resources and to make their research more efficient.

Visual Language Is International

For the DFG, Lothar Krempel has researched how these kinds of networks form. In doing so, he utilized information dating from 2002. His diagram illustrating the field of biology provides a very nice depiction of how strongly networked the research community is in this area. As expected, the key players are the universities, being the only institutions that receive funding from the DFG. They are grouped around Munich's Ludwig Maximilian University, which has clearly been particularly successful in its attempts to obtain funding. The university in Munich, in turn, cooperates with many other institutions of higher education. Thus everyone benefits, as the other universities are able to put their own funding into the pot, as well.

Photo: MPI for the Study of Societies/Christel Schommertz

What is especially interesting for the DFG, and for the Max Planck Society, is another finding: a large number of non-university research institutes also participate in the network – although they are not allowed to apply for DFG funding. The Max Planck Institutes have a particularly strong involvement in the network, and bring in their own resources. Thus, Krempel's diagram can also be interpreted as follows: in the field of biology, the different research systems in Germany are so extensively linked that their joint financing achieves a greater effect. This fact was hidden in the mass of DFG data, and only the graphic produced in Cologne made it easily accessible.

Network visualizations have another strength, as Krempel explains. "Someone from Japan or Africa can read the data, too, which is the really exciting part. These kinds of pictorial representations speak an international language, something that is naturally extremely important in today's electronic communication age." Unmistakable proof of this is the fact that his OECD diagram made it into the New York Hall of Science. That picture has a life of its own anyway: after it was published in a German computer magazine, its author received a phone call. The caller was a German banker working in the import and export trade. According to Krempel: "He was really excited and spent half an hour telling me how he'd found his 20-year work history mapped out in that diagram – so the picture really does show what is behind the OECD's figures."

His pictures often provide the Cologne-based social scientist with such unexpected moments. Many times it's an offhand response that tells him he's hit the nail on the head, he observes with a smile. And then all he says is, "Do you think I can't see that?" ROLAND WENGENMAYR