Prelude

Luca Giuliani

Just as did previous editions, the fifth installment of *Köpfe und Ideen* gives us portraits of a select number of this year's Fellows. Most of the pieces are by journalists who are inquiring into the work of individual scholars from the perspective of outsiders to the certain fields under examination. Sole exception is the portrait of the mathematician and physicist Marie Farge, which was composed by a Co-Fellow, who helps to bridge that supposedly very wide gap between natural science and the humanities. The writer Martin Mosebach, for his part, has composed a little love letter to the Berlin winter – *Letter from Berlin* – which is just the thing for conciliating even the most vehement haters of this season.

In Maurice Weiss' photographic portraits we see the researchers together with their luggage; although the Fellows are in so many other ways a varied and colorful group, they are astoundingly similar in this respect, for logistics creates a conspicuous common denominator. But it remains to be seen whether, after their year at the Wissenschaftskolleg, the Fellows will still have a suitcase in Berlin, as the old song goes.

Content

Moral Progress?

The New York sociologist Steven Lukes is writing a philosophical-cum-sociological inquiry into morality and must grapple with the question of moral progress

Fellow 2009/2010

Interview: Ralf Grötker

Ralf Grötker: These days there is much discussion as to whether, in the foreseeable future, countries like Turkey or China will be accepting of human rights to the same degree that they are accepted in the West. On the other hand, there are some voices that pretend we in the West have still not attained the terminus of our moral development – for example, because we are still quite happy to eat our fellow creatures – namely animals. The American writer Jonathan Safran Foer, whose much-discussed book Eating Animals pillories the cruelty of large-scale livestock farming, believes that in twenty years the majority of our meals will be vegetarian. And so it is against this background that I find it interesting to know the answer to the question: What do we understand by the term "moral progress"? And how is something like moral progress even possible?

Steven Lukes: Moral progress, and progress in general, was an idea that had its origin in the Enlightenment – an upward movement of humanity as such. For instance, this notion is succinctly expressed in [Marie Jean Antoine Nicolas Caritat, Marquis de] Condorcet's "Esquisse d'un tableau historique des progrès de l'esprit humain [1794]".

(Lukes standing up and pulling down an antiquarian book from the shelf.)

I'm presently preparing a new English edition of this work. Condorcet was the last of the philosophers – those critical intellectuals in pre-revolutionary Paris. Toward the end of his life he was persecuted by the Jacobins and died in prison in 1794. His Esquisse was written in hiding while on the run from them. I find remarkable the optimism that, despite everything, this work displays. In the Esquisse one can read: "The moral goodness of man, the necessary consequence of his constitution, is capable of indefinite perfection, like his other faculties." And: "Nature has linked together in an unbreakable chain truth, happiness and virtue."

This combination of ideas – the perfectibility of man and interdependence of attaining a true understanding of the world, living an ethically worthy life and experiencing wellbeing – can later be found in Hegel and then Marx and innumerable other nineteenth-century theoreticians of progress and modernization and on into the

twentieth century with more of the same, culminating in Francis Fukuyama's triumphalist idea of "the end of history", according to which the alliance of liberal democracy and capitalism has achieved everything that there is for humanity to achieve.

Grötker: Does this history of progress also describe our present?

Lukes: Today in particular the political Left, which has traditionally always represented a progressive line, is no longer certain as to what its aims for the future are. Socialism – what does it signify today? Fine, the name itself stands for a social, political and economic system that is more just and more efficient than capitalism. But what is it supposed to look like? My friend and colleague Claus Offe (Fellow of the Wissenschaftskolleg 1991–92) is of the opinion that today progressives shouldn't pursue new ideas but should rather concentrate on defensive policies in order to get a grip on the catastrophic consequences of what we call "progress." Among these are, for example, increasing unemployment and the growing strains on the social system; and, given these tendencies to regress, the challenge of making good on the promises of a social democracy. I believe that Offe is right about that.

Grötker: But is this skepticism warranted when it comes to morality?

Lukes: Let's first attempt to pose this question by making morality the object of a social-scientific investigation.

Grötker: And how do you propose to do that?

Lukes: Helpful for our purposes, I believe, is an understanding of morality that stems from the tradition of the so-called sentimentalists – that is to say, from eighteenth-century philosophers like David Hume and Adam Smith. According to this tradition of thought, morality is a normative system that has to do with a spectrum of specifically human moral feelings which it can express as well as channel. Among these feelings are sympathy, guilt, shame, regret, remorse, pride, gratitude, contempt, disgust, and so on. These feelings, it would seem, have developed from biologically prepared feelings, and it is conceivable that animals also have at least some of the prerequisites for morality.

Grötker: Most moral philosophers – at least those whose ideas are in the Kantian tradition – would for their part reply that feelings or sentiments, for instance sympathy, have nothing to do with morality but are something else entirely, for morality is accompanied by moral judgments – judgments with regard to that which one should or should not do from the moral point of view. And such judgments require a special form of justification; a justification from an impartial standpoint, and one doesn't attain this impartial standpoint by means of

feelings. And of course animals are unable to render these kinds of grounded judgments.

Lukes: My understanding of sentiment is that it consists in the disposition to feel something. And sentiments enter into morality. But in coming to moral judgments we don't necessarily experience a certain feeling at the very moment that we make these judgments. We don't need actually to feel indignant in order to find something scandalous. Furthermore, at least with humans, there are socially shared norms for what are considered suitable sentiments in certain situations. In the final analysis, therefore, it is norm-governed sentiments, as it were, that enable us to judge actors, actions, and attitudes.

Grötker: And how then do we conduct empirical research on this concept – how do we operationalize it?

Lukes: Well, take the ultimatum game!

Grötker: One person holds a sum of money that he can share with another person to whatever amount. If this second person, knowing the total sum, accepts the offered amount, then both individuals can keep their respective amounts . . .

Lukes: . . . and if the second person rejects the offered sum because he deems it unfairly small, then both players lose everything.

Grötker: So what does all that have to do with moral progress and norm-governed sentiments?

Lukes: In economic behavioral research the ultimatum game is an experiment the point of which is to ascertain whether there are distinctive moral features that there are revealed in widely different cultural and social settings, some common and some variable.
So, with the help of the ultimatum game it was discovered that most people involved in the experiment react similarly. They reject offers that appear to them too niggardly and therefore unfair – even if they themselves then go away empty-handed. And that's precisely how this experiment chips away at the image of homo oeconomicus. But there are variations. For example, in application of the experiment to members of the Lamelara, the Indonesian whaling people, they placed greater value on an equitable division than people in Europe, America, or China.

Grötker: Perhaps because they've remained relatively untouched by our Western culture?

Lukes: They also did this experiment with so-called primitive peoples in the Amazon region, who live almost completely sealed off from the rest of the world – and they behaved exactly like their Western counterparts. The experimenters explained the Lamelara results by the fact that for whalers close cooperation and absolute dependability are matters of survival. In my opinion

the experiment shows that what people feel is a "fair" amount in the ultimatum game is clearly dependent on cultural norms – on hierarchies, on opportunities for advancement within a society – all this goes to forming a person's emotional reaction.

Grötker: But then all that also means that there is no moral truth that can be attained. Moral progress, therefore, is no simple matter of locating and discovering certain moral truths. That which is seen as an appropriate sentiment is rather a matter of negotiation, of personal or even collective-historical experience . . .

Lukes: . . . Yes – of reciprocal interpretations. At the same time, in terms of the question as to appropriateness, there also resonates something akin to what you referred to before as the idea of the impartial standpoint. It seems to me that the impartial standpoint – what Adam Smith called "the impartial observer" or "the man in the breast" – whom we consult when we arrive at moral judgments, is a kind of psycho-social version of the Kantian authority known as "conscience"; only, in this case, the authority is embodied in real human beings who take others into consideration in concrete situations.
We ask our alter ego: "Seen from a disinterested point of view, what is the proper way to feel?" Here it is not simply a matter of judging something as morally good or bad but rather always a practical matter of certain sentiments and the question of their appropriateness. I find it to be a rather narrow endeavor reducing things solely to the idea of moral "oughts" – as one still finds today in Kantian moral philosophy. We can derive little directly from Kant's philosophy in terms of how to act in concrete situations.

Grötker: That wasn't his objective.

Lukes: But we still have the question of what is the right way to act.

Grötker: Does that mean that contradictions in moral judgments can only be traced back to diverging evaluations of what we would deem as the appropriate sentiment in a specific situation?

Lukes: When you look at history or compare the various cultures of our contemporary world, you quickly notice that there is a vast range of moral systems and that moral views in one society often diverge sharply from others. That often has to do with the fact that another segment of the spectrum of sentiments is being particularly emphasized – guilt, honor, or shame, for instance. And with individuals as with societies, people sometimes pursue very different values – personal autonomy being what is most important to some, and family solidarity to others.

Grötker: We have now spoken of various moral views. Where does moral progress come into all this?

Lukes: First of all, we're talking here about the development of norms, not about actual behavior. For example, although slavery was abolished long ago, in actual fact there is perhaps more slavery today than a hundred years ago. The difference is that you can't publicly condone slavery anymore. So progress in this area means that something like slavery, or rape, or the disadvantaging of women is at least today widely recognized as illegitimate – even if women in many places continue to be disadvantaged and, even worse, cruelly mistreated, for instance the treatment of widows in India or the brutal sexual assaults that are the order of the day in the Congo. This said, I should like to distinguish between three explanations of moral progress.

Grötker: Number one?

Lukes: Together with philosophers like Amartya Sen or Martha Nussbaum, I proceed on the assumption that there are basic prerequisites, or basic capabilities necessary to human functioning. One can draw up a list of capabilities necessary to leading a life of human dignity, and on such a list one would find things such as bodily integrity, shelter, being able to read and write, as well as the possibility of moving about in and public without a sense of shame. One may dispute one or another of these items in such a list, but basically I am of the opinion that one can indeed come to some kind of agreement as to its constituents. Progress would then mean simply making these basic prerequisites ever more accessible to more and more human beings – or, as an initial step, to at least instill the recognition that they constitute real entitlements, or human rights.

Grötker: Okay, and number two?

Lukes: Along with these basic prerequisites for a decent and human life, I believe that there exists something like fundamental feelings. Seeing human suffering, for example, places us under stress; even babies have an experience of this; this feeling is as universal as the disgust for bodily fluids. Accompanying these are moral norms that forbid any actions that would cause pain and suffering. Such norms vary, of course, according to the circle of persons that come under their sway as well as with regard to the kinds of pain and suffering under consideration. My supposition is that the historically observable turn away from corporal punishment and our increasing sensibility with respect to the cruelties inflicted on animals can be explained by the fact that such a strong feeling as compassion has been able to assert itself over and against other factors over the course of time. And this is happening because our emotional ability to feel compassion, taking the long view, facilitates the cultural evolution of norms that are pertinent to this feeling. That also explains, for example, the worldwide progress being made in abolishing the death penalty, first in the European countries and gradually in the United States, which as early as the 1970s declared the death penalty to be anti-constitutional. The only odd

man out in this regard is China, where thousands of human beings are executed each year.

Grötker: What is the third explanation for moral progress?

Lukes: Along with fundamental feelings, there exist values that have a certain primacy – for example, because they are a precondition for the ability of other values to be realized. Health would be an overriding value in this sense – which perhaps helps to explain the remarkable success of non-smoking laws in various countries.

Grötker: In the research one reads of various reasons for why the smoking ban in the workplace, restaurants and bars was first accepted in the United States and only thereafter in Europe. Initially there was no great expenditure involved in following the new rules. In the majority of restaurants, for instance, there are non-smoking sections. And in those places where the expenditure is greater – for example on long-distance flights – there was in consequence resistance. Also playing a role was the fact that violations of the new non-smoking regulations were relatively difficult to hide. There are also no pronounced subcultures in whose ranks smokers could find a haven. And finally, legislation itself also played a role in the general acceptance of non-smoking rules. Studies also show that smokers themselves were in greater accord with the non-smoking rules when these were legally mandated or if the smoker had had previous experience of the rules. All of this speaks to the fact that factors entirely different from fundamental feelings and overriding values serve as the trigger for changes in norms . . .

Lukes: My question is not so much concerned with what triggers these changes. I am more interested in why a certain value gets established. What can also be observed in the case of the non-smoking laws is that there is something like a need for consistency, for avoiding cognitive dissonance. Once the dangers of secondary smoke become known, people's behavior will sooner or later change accordingly – simply because this knowledge will induce smokers to feel bad about harming their fellow human beings.

Grötker: Isn't the situation similar with respect to our growing consciousness that there is something not quite right about our consumption of animals? Perhaps in twenty years most of our meals will indeed be vegetarian. The parameters would in any event seem to be present – there would be no great expenditure for anyone, there exists no pronounced minority culture, and we are gaining increased experience in terms of a vegetarian diet.

Lukes: At the end of the eighteenth century, Condorcet posed the question as to how anyone could justify the fact that "the rights of man" were denied to half the

human race, namely women. These are the type of questions that are responsible for the dynamic of moral progress because it is through them that moral norms attain to greater universality. As a result of moral ideas the differences between man and woman, between ethnic groups, and perhaps also between humans and animals will increasingly become unacceptable as arguments for justifying varying forms of treatment. Therefore, yes, perhaps in the foreseeable future our moral progress will indeed make us into vegetarians.

The Tumult about Turbulence

The French physicist Marie Farge is trying to come to grips with the problem of turbulence through the application of wavelet theory

Fellow 2009/2010

by Claus Pias

As opposed to your normal everyday computer – which performs one task after another with a kind of bureaucratic stolidness – vector processors calculate various data all in a single operation. Instead of viewing the world as one long queue in which you simply have to wait your turn to get what you want, vector processors have a systematic way of picking out things that are similar to one another and dealing with them in one fell swoop. Vector processors are of greatest advantage when a large amount of data needs to be worked through in similar fashion. But this data has to first be available and then be employed at the very same instant. And here is where the problems begin – problems with which Marie Farge began to grapple three decades ago when she wrote the test programs for the legendary "Cray 1."

In its day the "Cray 1" was the fastest computer in the world. A slender octagonal column with a hundred megaflops (a million computational operations per second) and a revolving bench under which a Freon cooling system was concealed, five and a half tons in weight, consuming some two-hundred kilowatt hours, designed by a single person and wired by the hands of innumerable women. Back then, women were often responsible for the subcontracting work – but Marie Farge was not one of these. Still today she becomes rhapsodic when discussing those days. Without a moment's hesitation, she can trace for you the computer's architecture, sketching its registers, memory banks, and pipelines; she knows the nanosecond cycles of the various storage-access components, and can still write a fluent "Assembler" program. In her day she optimized matrix multiplications, for which vector processors are beautifully suited from an architectural point of view. The difficulties involved in this are not in terms of mathematics but in terms of organizing the computation. How do you populate the 64 lightning-fast vector registers with data from the eight slow memory banks while losing as little valuable time as possible through storage access? Marie Farge's solution has the charm of a successful "hack." Her idea was that if you expanded the matrix then the hardware specifics and the idiosyncrasies of the compiler (which automatically translates the Fortran code for the vector processor) could suddenly interact to the extent that they would drastically reduce the loss in speed sometimes involved in random-access procedures. At

the time, in Farge's capacity as physicist, the "Cray 1" was less important as a mathematical tool than it was as an experiment in the field of physics.

If the thesis is correct that a variety of languages and tools operate on our thinking whilst subdividing the world in different ways, then the programming of vector processors promotes a kind of thinking in terms of similarities. Marie Farge teaches and performs her research at the École Normale Supérieure in Paris, and in listening to her speak one is overwhelmed by the speed with which she draws correlations between scientific computing, the history of physics, mathematics, and phenomenology as well as by her fleet-footedness in darting back and forth between highly specific details and fundamental questions. And this could quite possibly be the essence of her research – the search for coherent structures and their non-linear interaction on multiple scales.

Marie Farge – who is often in Nagoya and Tokyo and whose apartment at the Wissenschaftskolleg exudes a kind of Japanese clarity and calm – is preoccupied with turbulent flows. Of course, our life-world is filled with such turbulence – from the braided smoke of a cigarette to the clouds of milk in our morning coffee to atmospheric currents and those in the oceans of the world. And because we are surrounded by such flows in our everyday life, we take for granted that which is in fact endlessly complicated. Our perceptual faculty tells us that cigarette smoke first rises upward and that it then at a certain point begins to twist and braid itself and then finally dissolve into thin air – all of this in a different form, but always in a similar fashion. But to adequately describe this process is one of the last great unsolved problems of classical physics. It is also one of the seven Millennium Prize Problems of mathematics, for whose solution the Clay Foundation has offered prize money of one-million dollars – going under the designation of the "analysis of the existence and regularity of solutions to the three-dimensional incompressible Navier-Stokes equations."

Naturally, scientists have learned to deal with turbulence in all kinds of different ways. On the one hand, one can get a bead on such phenomena through statistical approaches so as to predict mean-values as well as make predictions with regard to the various classes into which certain cases might fall – at the price of generalizing, of course, and this, for instance, at expense of spatial boundaries; while on the other hand, one can deal in a practical manner with certain individual cases because in the field of technology – for example in the industrial sphere or that of aircraft manufacture or the construction of motors – one is required to deal with turbulence in an operational way and find satisfactory ad hoc solutions. But a theory of turbulence in and of itself is not on the horizon and the research into it is still in what one might term a pre-scholarly phase. Of course, we know the base equations in the field of flow-dynamics (the Navier-Stokes equations) which are the "first principles," of a turbulence theory to come but

there is not yet a proof that the solutions exist and remain smooth for all time when the flow is turbulent.

It is in this respect that Marie Farge can be seen as a contemporary of Hermann von Helmholtz, who in 1858 put forward his propositions regarding the conduct of vortices in fluids, or of Osborne Reynolds, who in 1883 came up with a measure of the ratio of inertial forces to viscous ones, thus denoting the transition from smooth (laminar) flow to chaotic (turbulent) flow. Marie Farge's questions are just as fundamental and are in the tradition of classic Cartesian epistemology – What are the essential building blocks of turbulent flow? How can they be abstracted? What sort of laws do they follow? How are they connected to one another? As early as the first international turbulence conference, which was held in Marseille in 1961, Hans Liepmann from Caltech made the assumption that such coherent structures (permitting the analysis of turbulent flow) could indeed exist. Were one to identify such structures, then a general theory could be posited and the deterministic chaos of turbulence modelled. This would be invaluable information, facilitating research into everything from the single flap of an insect's wing to circulation of the global climate.

Yet the matter is by no means made easier by the assumption hitherto that these "atoms" of turbulence are very likely vortices – for how, where and why do these vortices form? How does one identify individual vortices? How does one distinguish between those vortices that are important for development of the flow dynamics and those that are not? And what degree of detail must be taken into account if it is indeed a fundamental feature of non-linear processes that small perturbations can have surprisingly large effects? Turbulence also takes place on a wide variety of scales, but a complete solution to the equations of motion – a "direct numerical simulation" (DNS) – on all scales is only possible within certain bounds. What means does one employ so as to separate matters of principal importance from those of only secondary significance? How does one separate the meaningful nexus from the inconsequential background? And how does one solve the problem of scaling?

It is Marie Farge's conviction that our conception of turbulence changes with the vehicles we use to investigate the phenomenon. It was no later than the 1980s that the computer had already emerged as a way of complementing the categories of theory and experiment, namely through its simulation of "numerical experiments." And new procedures for the analysis of data emerged that would have been inconceivable without aid of a digital computer. Both of these play central roles in Marie Farge's work: The technology employed by Marie Farge is "wavelets," which is an expansion of the Fourier analysis, this former originally developed in the 1980s, and is now absolutely indispensable to signal processing. The simplest way of describing their application is that they serve a compressing function in picture files. As such, "wavelets" separate useful information from that which is redundant and they code it in a

deft and skilful manner – so as to separate it from that which would only congest the computer's memory. Therefore, compression processes are not only optimizing tools but also instruments of recognition because they succeed in providing structural information.

It is this structural analogy between the filtering of information and the filtering of vortices that links "wavelets" with the search for the constitutive elements of turbulent flow. How does one distill that which is important from that which is not? Through the use of "wavelets" it would seem possible to filter and mathematically express precisely that which one hopes to discern in turbulence. On the one hand "wavelets" constitute an efficient tool of multi-resolution analysis while also functioning as a mathematical microscope with adjustable focus, and on the other the compression process itself is based on the ascertainment of coherent structures so that the large "wavelet" coefficients correspond to the coherent components (the vortices) and the small "wavelet" coefficients to incoherent components (background). But we needed Marie Farge's talent for drawing correlations to be able to emerge with these coherencies. Perhaps vortices and turbulence are no longer that which they once were before the onset of computers – but true also perhaps is the remark of Heinrich Hertz, the pioneer of electricity research, who Marie Farge likes to quote: "One cannot escape the feeling that these mathematical formulae have an independent existence and an intelligence of their own, that they are wiser even than their discoverers, that we get more out of them than was originally put into them."

Can Ants Count ... Compute ... Calculate ... ?

The biologist and historian of science Manfred Laubichler is tracing the mechanisms entailed in the animal kingdom's division of labor

Fellow 2009/2010

by Julia Voss

Arguably the three main geographical features of the state of Arizona are its vast desert to the southwest, the Grand Canyon to the northwest, and the capital city of Phoenix, where people have swimming pools like folks in other parts of the country have garages. From this standpoint alone, Arizona is probably not the first locale that comes to mind when thinking of places for a serious biologist – and an Austrian one at that – to ply his trade. But Arizona is indeed the locale where Manfred Laubichler, native of Salzburg, has been teaching and researching for the past nine years. Having done his undergraduate work in Vienna, having received his doctorate in biology at Yale University, and then having acquired a Ph.D. in history from Princeton – what in God's good name should have brought him to the Arizona desert? What was it that enticed this biologist to settle in Tempe, where Arizona State University is located?

In telling Manfred Laubichler's story, we must start in his homeland of Austria, that country to which Bruce Chatwin devoted a chapter in his book *Songlines*. The English travel writer describes how he made a pilgrimage to Konrad Lorenz, the "Father of Ethology." Chatwin had no illusions about Lorenz, who was involved with the Nazis, and he had read Lorenz's book *So-Called Evil* (1963), but he was nonetheless fascinated by this elderly man with the sunburnt face who received him in his Altenberg garden. During the course of their interview, Lorenz began to give an unforgettable description of two male sticklebacks fighting. Chatwin writes that Lorenz "clasped his hands beneath his chin and splayed his fingers to simulate the quills of the sticklebacks. He grew red around the gills. He turned pale. He swelled up and detumesced; he sprang forward and backward." To his surprise, Chatwin learned that Lorenz was not only an excellent imitator of animals but that he was a person who had the almost childlike need to share his enthusiasm regarding his discoveries. One could also term this a kind of national characteristic. Austrian biologists are interested in the big questions – from Konrad Lorenz to Rupert Riedl to Irenäus Eibl-Eibesfeldt. They gnaw so pertinaciously on these big questions that, as Manfred Laubichler puts it, "they become a bit daft." He himself studied with the marine

biologist Rupert Riedl, who is an evolutionary scientist and co-founder of the Konrad Lorenz Institute for Evolutionary and Cognitive Research in Altenberg. And Laubichler, too, of course, entertains a big question: How does the division of labor arise among animals? And this question encompasses all aspects of life, in both microcosm and macrocosm, from the genome to cells to colonies of insects.

As an Austrian, therefore, Laubichler has perhaps a slight edge on others of us in terms of his being able to understand that it is the big questions with which biology must wrestle and which make this discipline so exciting – but that it is also the big questions which can easily lead one down the garden path. And that is why it is so important to know history. In 2006, along with historian of science Michael Hagner, Laubichler published a volume of essays on this theme: *Der Hochsitz des Wissens: Das Allgemeine als wissenschaftlicher Wert* (*The High Seat of Knowledge: The Scientific Value of General Knowledge*). As the title indicates, the book treats the important role that general knowledge played in nineteenth and twentieth-century science. It is an error to believe that in the course of the modern era the sciences fragmented into ever smaller and more isolated fields of expertise; for example biology, under the auspices of Charles Darwin, founder of evolutionary theory, was always addressing the big questions at the same time as it was being subject to institutionalization, professionalization and technization. But as Manfred Laubichler has written in a recent article for the *Encyclopedia of Life Sciences*, any biological knowledge that leaves its imprint on our self-understanding is "always of a political nature." Laubichler does not believe in a science that is isolated from the world and interested in knowledge solely for its own sake. And he clears up a serious misunderstanding – that a knowledge of history is irrelevant to the practice of science. Professors in the natural sciences frequently regard the history of science as a kind of curio shop full of discarded and useless ideas; but whoever holds fast to this image can then imagine Laubichler as someone who regularly turns up Picassos at the fleamarket. It was in 2007 that he, together with historian of science Jane Maienschein, published the book *From Embryology to Evo-Devo: A History of Developmental Evolution*, which was a history of developmental biology from its very beginnings to the present day. Laubichler's primary interest in this regard is the nineteenth-century German biologist Theodor Boveri, who studied the heredity and development of sea urchins. According to Laubichler, what Boveri observed at his zoological research station in Naples is of no less interest a century later . . . and thus we have the third strand in that weave of interests which drew the Austrian across the ocean to America and finally to the Arizona desert: biology, history, and the possibility of combining the two in scholarly research. It was Arizona State University which placed the necessary resources at his disposal so that he would not have to decide for one discipline or another. There are more than 120 professors at the university's School of Life Sciences; the

Center for Social Dynamics and Complexity, which Laubichler leads, has over twenty-five members on a staff composed of anthropologists, historians, philosophers, computer scientists, and psychologists.

What "division of labor" in the animal kingdom means can best be understood through an examination of the world of ants – which is precisely the research focus in Arizona. One of Laubichler's colleagues, with whom he closely works and jointly publishes, is the ethologist Bert Hölldobler, who is also a Fellow at the Wissenschaftskolleg and who has taught at the School of Life Sciences and the Center for Social Dynamics since 2004. Hölldobler's most recent publication, together with Edward Osborne Wilson, is *The Superorganism: The Beauty, Elegance, and Strangeness of Insect Societies* (2009). Hölldobler has been studying ant-behavior for decades now, and fascinating for him is the fact that ant colonies are organized entirely along eusocial lines in which there is a division of labor even in terms of reproduction. A typical ant colony consists of an egg-laying queen, a host of infertile females, and males who die shortly after mating. Their highly organized division of labor gives researchers a possible clue as to the developmental evolution of ants, for although their genomes are practically identical, the various kinds of ants in a colony can be clearly distinguished in terms of phenotype. As they grow to maturity, certain ants are nourished and reared to perform certain tasks – for instance, the soldiers with their brawny jaws. Apparently the number of soldiers that a given colony might require is in fact the product of a computation. In the American state of New Jersey, for example, there exist no fire ants that assault other nests, and so colonies there train fewer soldiers than their counterparts in Florida, where there is the daily threat of predatory raids. Moreover, in an experiment where a number of soldier ants were removed from a colony, the colony built up their numbers once more to compensate for the loss and attain its previous level. Ants can count and can communicate these numbers to one another through chemical means. Even more knotty than the problem of deciphering the code used in this communication system is the question as to how this certain code developed. In another experiment, two queen ants were sequestered with one another – and with the astonishing result that they soon divided up the labor, the one queen laying the eggs and the other taking on the responsibility of feeding the offspring. But how do such hierarchies arise? Are there certain structures regulating social behavior which have evolved over time? Do individual ants perform the role of agents through some kind of in-built base-calculation that they have at their disposal?

It was for questions of precisely this nature that the Center for Social Dynamics and Complexity was established at Arizona State University. Laublicher says that the objection to such a comprehensive research program was the notion that to break human behavior down to such a reductionist schema would be unsettling for many, so "Dynamics" and "Complexity" were included in the institute's title – the title becoming the institute's

manifesto. Scientists have long abandoned the neo-Darwinistic notion that genes constitute a kind of black-box which can tell us everything we need to know about the (predetermined) behavior of organisms. At Arizona State they are interested in communication, feedback-loops, regulatory developmental systems as well as systems of exchange – all of which can be observed in the growth and differentiation of multicellular organisms, in the lifecycle of ant colonies, and in the development of institutions and cultures. This interest is what unites historians like Jane Maienschein and zoologists such as Bert Hölldobler and Manfred Laubichler, who has a foot in both fields. In the midst of a wide array of field specialists, Laublicher has a kind of genius when it comes to presiding over collaborative work. Berlin is an ideal workplace in this regard because it is rich in scholarly opportunity – something that Laublicher already discovered during his regular research stays at the Max Planck Institute for the History of Science. His research on the evolution of the division of labor is best advanced in cooperation with colleagues – and through a proper division of labor, of course.

The Dyke Thinker

An encounter with the art historian and image-scholar Horst, Bredekamp whose work oscillates between the vita contemplativa of ritual retreat and the vita activa of institutional engagement

Permanent Fellow

by Alexander Cammann

There, where the sheep safely graze, is also growing, from one year to the next, an important humanistic work. Midway between Garding and Oldenswort, the birthplace of Theodor Mommsen and Ferdinand Tönnies, on the peninsula Eiderstedt in North Frisia, is the Rehmstacker Dyke – and here, in close proximity to the North Sea, is the house to which Horst Bredekamp retreats each year to spend eight to ten weeks writing. Bredekamp has worked here, in peace and solitude, not far from the tidal flats, for going on thirty years now, developing those ideas and inspirations that he has collected throughout the year. With the exception of his wife, Bredekamp is completely sealed off from the world here – and with the exception of a single telephone call on a set time each day with his student assistants so as to give them instructions and address unfinished business. "When it comes to writing, I'm autistic," says Bredekamp. "I can't stand people talking around me when I'm writing, and any electronic gadgets are taboo." This intensive period of writing is a yoke that the art historian voluntarily shoulders, for in this quiet zone far from the scholarly rat race, book after book has been produced.

Horst Bredekamp is a puzzling figure. His productivity is breathtaking. The number of his offices and functions exceed all human dimensions. His appointment book this side of his fixed-term North-Sea solitude is as densely packed as that of a top politician or chief executive. Yet the vibrating tautness of his intellect seems indefatigable. If Umberto Eco has a lookalike double, as the pretty rumor would have it, then this must hold equally true of Bredekamp. "Yes, clearly as of late it's been too much," he sighs. "It has to be less" – and his auditor immediately suspects that this thought has not for the first time been uttered by the art historian. He is both restless and has a certain nervous, absentminded charm – which of course is a mask for his sustained concentration and intense presence. The Berlin-Brandenburg Academy of Sciences and Humanities and the German Academy of Natural Scientists, the "Leopoldina" in Halle, are proud to call him a member, and the Wissenschaftskolleg, where he was a Fellow in 1992–93,

made him a Permanent Fellow in 2003. Ever since this appointment, Bredekamp not only takes part in the Wissenschaftskolleg's weekly colloquium and the other opportunities for intellectual exchange that it has to offer, but he is a key player in setting its agenda and highly influential in terms of precisely which scholars are to be appointed as Fellows in the coming years. "The miracle of it all," says Bredekamp, "is that the Wissenschaftskolleg's Tuesday Colloquium never gets old; every new crop of Fellows has its own character, and I still go to every colloquium with a certain festive excitement." Alongside of his Wissenschaftskolleg activities, he is also in charge of several large research projects at Berlin's Humboldt University, where he has taught since 1993; he has done much to shape and leave his imprint on the university's Hermann von Helmholtz Center for Cultural Techniques, and for whose sake he refused an appointment to the Biblioteca Hertziana in Rome – which, mind you, is a Max Planck Institute. He was member of the Wissenschaftsrat's commission on the "Future of the Humanities" and the "Future of Media Sciences," and he has been member of innumerable advisory boards for endowments and institutions both in Germany and abroad. The life of a scholarly organizer naturally requires a pronounced will to configure things, but you believe Bredekamp when he describes his work on large-scale research projects and in institutions as having its source in an inner sense of duty. "It is a privilege to be able to pursue my intellectual work," he says. "And so I have the obligation to give something back to the institutions that enable me to do this work." Moreover, the collective work entailed in these self-imposed obligations – along with his writerly autism – is also extremely satisfying; the mental stimulus he receives from his students, staff, and fellow scholars has always been of immense importance in Bredekamp's ideational world. The breadth of his intellectual interests can be indirectly seen in the voluminous festschrift assembled by his students for Bredekamp's sixtieth birthday and to which many who are not art historians contributed essays. And there are several pages with photographs of the still today enthusiastic soccer player in action; perhaps his most popular book is that on the importance of *calcio* during carnival in the Florence of the Medici – as mass amusement and a phenomenon symbolizing the status of the power elite.

In view of the realities of today's major research projects, it must indeed be regarded as a minor miracle that over the years Bredekamp has not mutated into a self-complacent powerbroker. But nothing of the sort. He is, rather, that rare embodiment of an influential arts scholar whose curiosity remains undiminished despite his accumulation of vast institutional capital; for this captain's son, born in Kiel in 1947, delight in knowledge and in formulating insights has never waned. For Bredekamp, the results of his cognitive process never ceased to surprise him, and these results are not something, he laughs, "that are subject to your free will." He tells the story of how one evening he was on his way home, tired after a long day at the Wissenschaftskolleg, when he

stopped at a red light and was suddenly overcome by a thought that utterly reversed the hitherto central positions he'd assumed in his theory of the *Bildakt*, or "image-act." This episode occurred in October 2009, and the fruits of that experience can be read this autumn in the book *Theorie des Bildakts*, which he worked up from his Adorno Lectures in Frankfurt in 2007.

My ideas precede my facts," he says, "and it's always a particular strain for the facts to finally catch up with my ideas." The detail work can last a long time, explains Bredekamp – he needed five years for *Die Fenster der Monade* (2003 [*The Window of the Monad*]), which dealt with the philosopher Gottfried Wilhelm Leibniz's visual considerations as prerequisites for his system of thought; for eight years he reflected on Thomas Hobbes' *Leviathan* and his picture of the state (1999); and it was almost twenty years after his initial ponderings that in 2007 he finally published his examination of the scientist Galileo Galilei, whose astronomical discoveries would have been impossible without his artistic ability. The Galileo book signaled the triumphal completion of Bredekamp's trilogy on the visual-artistic preconditions of scientific and humanistic thought – and here you have our scholar in a nutshell: a researcher with interests that reach far beyond the traditional and narrow parameters of art history and which develop in close interchange with other disciplines. There is an imperial sweep to Bredekamp's suggestive style of thought. In hearing him lecture you are pulled along in the dynamic wake of this obsessive speaker with the kindly manner; a dynamism that – even if you would sometimes like to resist it – are hardly able to escape. In a strange way his wiry figure seems to be both delicate and tough – and this blend is another fascinating aspect of Bredekamp, as is easily recognized by any schooled observer who has read his work on the representations of rulers and artists in the Renaissance. This overpowering aesthete appeals by virtue of his virtuosity. A bit of magic and charisma appertain to the role he plays. And it is to this degree that with Bredekamp you have – in both senses of the phrase – an aura at work.

In Bredekamp's view, the traditional questions and themes of art history that find their focus in great artists and their works – in "high art" – have proven to be too narrow in scope. And that is why, some years back, Bredekamp picked a fight with an entire conference of art historians by demanding an "insurrection" – although for many years, together with others, he has been pushing the boundaries of his field to meet the requirements of a full-fledged *Bildwissenschaft* – i.e. a discipline based on the historical study of images. This evolved discipline is to focus on the visual sphere in all its permutations as a central phenomenon of human existence, and this is what actually constitutes the Bredekamp project writ large. In his theory of the image-act, Bredekamp seeks to explain the paradoxical ability of ostensibly "lifeless" images to have so vital impact on us that they move us to action. Image scholarship as not only the cutting-edge discipline of our image-centric epoch but *the* universal theory of our

time? "I'm interested in how thinking works," says Bredekamp by way of explaining his motivation, and adding: "We think through forms." In such ideas one can discover perhaps the trace-elements of a materialism that has its roots in Marxism: Bredekamp's 1975 doctoral dissertation was entitled "Kunst als Medium sozialer Konflikte: Bilderkämpfe von der Spätantike bis zur Hussitenrevolution" ("Art as a Medium of Social Conflicts: Image Struggles from Late Antiquity to the Hussite Revolution"). "I never lost Marx," says Bredekamp, who confesses to making repeated use of him. And over the course of time he has taken other thinkers to his breast, above all Walter Benjamin and Carl Schmitt, to whose bipolar brotherhood Bredekamp dedicated a much-admired study. The intellectual backbone of his arguments is the thought of Aby Warburg, with whom Bredekamp is allied not least through their common fight against "border-cop biases" and their shared and "sincere loathing of art history that aestheticizes" (Warburg). Another leading light in Bredekamp's intellectual cosmos is doubtless Erwin Panofsky, who also – no coincidence here – had close contacts with scholars in other disciplines and wrote a remarkable essay on Galileo as artist.

An unusually creative generation of German art historians has substantially shaped the field in the last few decades – this not dissimilar to what has occurred in other disciplines in the humanities. Along with Bredekamp one might name Hans Belting, Gottfried Boehm, Werner Busch and a host of others, above all Bredekamp's ten-year-older academic teacher Martin Warnke. Is this mighty phalanx of intellect also a burden for the younger generation of art history scholars? Bredekamp seems not to think so: "There are excellent people coming up, Frank Fehrenbach, who's teaching at Harvard right now, or Ulrich Pfisterer in Munich – those are just two from a whole array of people." His generation, however, was able to profit from a comparatively early modernization process that took place in art history in the 1960s and which culminated in 1968 in the founding of the "Ulmer Verein," an association that sought to confront traditional art history with social-theory approaches and which continues to do so today. "At that time it was all about negating a negation," says Bredekamp. "In 1933 the humanities were decapitated when the Nazis sent first-rate scholars into exile. Methodological debates in art history – which up until that point had been a cutting-edge discipline – were broken off; and they weren't really resumed until the 1960s." And Bredekamp's generation, one might add, has done a splendid job of making up for lost time.

Awarded the German Academy for Language and Poetry's Sigmund Freud Prize for scholarly prose in 2005, bestowed Hamburg's Aby M. Warburg Prize in 2005, and crowned with Marburg's Richard Hamann Prize for Art History in 2009, Bredekamp is also a global player who has been an invitee of Princeton and the Getty Center in Los Angeles. What is there still to achieve? He smiles and speaks of a longstanding project that has preoccupied him for years and which must see

the light of day eventually – northern-Spanish Romanesque sculpture. Indeed, enthusiastic students can give account of group excursions along the Way of St. James to Santiago de Compostela. Much closer to home is another dream of Bredekamp's – and whose realization he is presently hard at work on – namely the Humboldt Forum in the heart of the German capital, just opposite Berlin's Museum Island. Bredekamp's idea is to place the historically important collections of the Humboldt University – collections that he has gone to much trouble in past years to display in places like the Martin Gropius Bau (a much-admired exhibition) so that people might rediscover them – in the rebuilt *Schloss*, the old Hohenzollern palace; and the Renaissance Art Chamber – that nucleus of the modern museum which Bredekamp has intensely researched – will be able to celebrate its resurrection in the *Schloss*. Artifacts from the world of art, technology and science, arranged in a stimulating composition – that, for Bredekamp, would be an "actualized utopia." After all, the two years he spent working in the Liebieghaus museum in Frankfurt am Main was perhaps the happiest time of his life.

Otherwise, there are certain "things for my old age" murmurs Bredekamp in passing, perhaps the big Michelangelo book . . . He doesn't need to be told how greatly anticipated this book is; 150 years ago it was Herman Grimm, one of his predecessors in the professorship Bredekamp himself now holds, who published a giant two-volume work on the artist. For the present we will have to be satisfied with the volume of Michelangelo essays that Bredekamp published in 2009 and in which he posits that the incomplete works and the limited time of this much-in-demand artist were the respective product and prerequisite of his creativity; that is, limited time was a problem in the sixteenth century as well. Nevertheless, Bredekamp opines that "time constraints such as these could lead to expedients that gave the epoch its signature" – and perhaps also providing us with a glimpse into the confident and hopeful heart of this author who is ever plagued for time? But one thing seems certain: that there will be still more intellectual signatures of our time from the dynamic thinker Horst Bredekamp, and all put to paper on his North Sea dyke.

“Something with Media . . .”

Can reflection on the media be institutionalized? Claus Pias asks himself what is to become of media studies

Fellow 2009/2010

Interview: Jürgen Kaube

Jürgen Kaube: Herr Pias, recently two new media-studies journals appeared – almost on the exact same day. Apart from one’s occasional impression that it would now and then be better for young disciplines if they didn’t grow all too fast and with the good articles spread across too many publications – what is “media studies” exactly? The trite answer would be research on communication techniques – but then one runs up against the problem that such research has been around ever since we can remember, only with different labels. These fields would be art history, sociology, archeology, political science, literary studies and film studies. In the meantime there is even “book studies.” What is the relationship of media studies to all that?

Claus Pias: From the standpoint of the history of science, interest in the techniques and material technology of communication within all these disciplines has not always had an easy time of it. For example, literary studies. For a very long time nothing was ever made of the fact that the print-medium was the precondition for novels in book-form or sometimes as serialized in newspapers or magazines. People always focused on the “intellectual” content; the production and distribution techniques as well as the possible mental-historical consequences for a “typographic age” were always treated as subsidiary matters. In the 1980s, when Friedrich Kittler tried to habilitate per the theme of writing-systems – a work which today is regarded as a classic – this topic was so inconceivable that he attained his habilitation only with the greatest of difficulty. In art history the situation was a bit better, for here they had something of a tradition of paying heed to the technical or medial preconditions of works. But even in philosophy, concepts like “technology” and “technique” and “communication” – as compared to such concepts as “praxis” or “consciousness” – became explicit objects of serious reflection only very late.

Kaube: Added to that, it seems to me, is the fact that for a very long while there was an odd underestimation of the role of techniques and technology – including their role in a cultural vein. For the longest time, technical and medial aspects have had a kind of subaltern status.

As late as the 1970s, Pierre Bourdieu authored a book on photography with the subtitle: "An Illegitimate Art." And just why was photography illegitimate? Because it was more technical than painting as well as being more in the nature of a mass medium. And in the same decade, when German Gymnasium teachers began investigating television, this was regarded – among others, by these very same teachers – as signaling a farewell to the Western tradition. To them, investigating the medial side of something was the first step toward abandoning the canon and cultivated values.

Pias: Absolutely correct. And of course one should never underestimate the political dimension involved in analysis of porno, comics, spaghetti westerns and TV series – all fairly disreputable among the academic clique – in the wake of the student unrest and concomitant social changes of the 1960s. Added to this are the technical media developments that also played a role in the emergence of media studies. Without the video recorder there would be no such thing as film-studies in college seminars. An additional difficulty is that "medium" is a functional concept which lies beyond the realm of individual media such as film, television and photography. Hence, the question is: What is the medial function fulfilled by something in a certain context? What kind of things can become a medium? And what kind of scope does a concept like "medial function" have? But such a functional definition of media – whether it be art, literature, music, physics, biology or law – presupposes a great deal of knowledge of their respective contexts. Or put in another way: Media studies must always be wary not to be caught up in superficial observations. And for humanities scholars there is also often a certain effort involved in attempting to batten on the technical knowledge affiliated with optics, acoustics, the radio, computers, or laboratory equipment.

Kaube: Right there we have a whole list of reasons for the unlikelihood of media studies. Nevertheless, the discipline has skyrocketed in the last twenty years, and in the meantime there are well over a hundred courses of study in media studies at almost fifty German universities. What is the reason for the discipline's popularity?

Pias: One reason is certainly the importance ascribed to the media – and this by the media itself. Growth of the discipline has paralleled what one calls the spread of the so-called "new media." People have concluded therefrom – often falsely – that a course of study in media studies would qualify them for working in the media. (In truth, it seems to me rather an attempt to overhaul the humanities.) A second point is that medial seachanges such as digitalization always mislead one into casting a backward glance at the dying media epoch immediately preceding. And lastly, we apparently live in a society which for decades has told itself tales of the power of media and reality as a media construct. One speaks of the "Fourth Power" when discussing newspapers and television. If someone runs amok with a gun,

going on a killing spree, then First-Person-Shooter games or the Internet are made to shoulder the responsibility. Entire generations are categorized and characterized according to the certain media that entered the market in their youth and formative years. Media studies would therefore appear to be the key discipline for analyzing historical eras.

Kaube: Let us pass over this historical analysis – in the end it is not much more than the species of text by which scholars secure their own presence in the media; and the media, alas, is being continually duped by it. In terms of students who seek to enter the media through media studies, would it not make more sense for them to realize their dreams by means of something more specific, such as the study of film or television, rather than something as broad as "media"? What would be the sense in a non-scholarly and professional or practical way of someone dedicating themselves to the learning of "writing-systems" or the history of cybernetics?

Pias: A Bachelor's degree in media studies, where you have six semesters of seminars on McLuhan, Kittler, the history of Indian cinema, the sociology of hiphop, and media psychology – all this is most certainly very interesting in and of itself. But it doesn't lead to greater applicability if you have a career in television or are doing editorial work on the Internet. It would presumably be better for an individual to study geography, history, musicology, or sociology and then, at that point, with the solid knowledge they've obtained in whatever discipline, try to make their way in some kind of media-related profession.

Kaube: Media studies would thus remain a purely scholarly discipline. But let's return to our initial question. No one today any longer disputes the importance of media in terms of literature, architecture, cognitive theory, or education. But does one require a specialized discipline to study such aspects?

Pias: Perhaps one can put it this way. Because the concept "media" is less involved with certain things than it is with a certain way of speaking about things – a problem of cognitive theory that crops up in all kinds of different disciplines, from aesthetics to medicine to computer science – the media-perspective, as it were, is now an integral part of these disciplines. Paradoxically, you have to retain and maintain the disciplines in order to change them. That's basically the case with gender studies, whose perspective functions best within the context of already existing disciplines. As a discipline of its own, feminism cheats itself of the opportunity of insisting on its basic argument in the context of specialized discourses. "Media" – that's a research approach in the very same sense, and not a discipline. Not only should media questions be pursued from the disciplinary angle but they can only be posed from the disciplinary standpoint because it presupposes a considerable amount of knowledge that is only acquired with diffi-

culty in that grab-bag course of study known as "media." Still, I consider the media question to be so central and productive that it is vital for us to think about new and suitable institutional forms.

Kaube: That's a recurring problem in the history of scholarly fields and disciplines. For example, how does a sociologist of law or literature avoid undercutting the level of knowledge and insight attained by the fields of jurisprudence and literary studies? Sociology eventually emerged as an individual discipline, and media studies have recently become one as well – in contrast to cybernetics or semiotics or structuralism, which were analogous approaches but which for the most part have not emerged as independent disciplines; rather, they provide certain approaches for the established disciplines.

Pias: By contrast, media studies have been steamrolled by the success of their pre-disciplinary perspectives. The question as to an epistemology of media has yielded extremely fruitful knowledge and insights in every imaginable sphere. In a very short period of time certain classics have emerged, and in a relatively short period of time most disciplines acknowledged that this perspective had a lot to say for it. But this success – one tends to forget – did not come within the framework of an institutionalized discipline. Rather, it was nomads within these disciplines who had to demonstrate a very special knowledge of their respective discipline in order to be able to propound their media-based approach at all. And thanks to this approach, they eventually crossed paths with nomads from other disciplines. For example, they weren't just dilettantes speaking in a "media-studies" way about imaging techniques in the media without having the faintest notion of medicine and medical informatics and whose impartations would never be heard by any kind of real physician anyway.

Kaube: Recently a conference was announced with the title "Media of Resurrection." Could it be that it is this kind of exploitation of the media question which irritates you?

Pias: Yes. I fear that if the media perspective comes only to mean that one can say something on every imaginable topic and hold a lecture with the imprimatur "Made in Media Studies," then we will be squandering everything we've achieved so far.

The Quantum Physics Gang

Jens Eisert, Tobias Osborne and Ulrich Schollwöck are investigating the secrets of complex quantum systems

Fellows 2009/2010

by Rainer Scharf

The rules are simple, but the game is sometimes so complex that even supercomputers are hopelessly overwhelmed when trying to analyze it. The game is quantum mechanics and the playing pieces are the myriad microscopic particles that interact according to quantum-mechanical laws. These particles may be the atoms in a table or the electrons in a superconductive crystal.

Although quantum mechanics was developed to describe atomic and molecular processes, it has turned out to be a universally valid physics theory. It can be applied to the field of nanotechnology and the world of macroscopic objects, even if its consequences – at times quite bizarre – largely remain hidden in this domain.

Over the past few years, researchers have developed a pragmatic approach to quantum physics that seeks to link it to information theory. One of their aims is to calculate efficiently the characteristics of quantum systems that consist of many particles. Another is to tap into the potential of quantum mechanics through new "quantum computers."

There have been many surprises. Some many-body quantum-mechanical systems can be effectively analyzed using present-day computers, although they work according to the laws of classical physics. But other systems that are not any more complex than these can only be crunched using quantum computers that have the capacity to perfectly reenact the quantum-mechanical "game."

Jens Eisert, Tobias Osborne and Ulrich Schollwöck work at the interface of these promising developments in quantum physics. "We're interested in various aspects of quantum information theory and quantum computing – and also in describing complex quantum systems," explains Jens Eisert, whose bubbling enthusiasm for the field is instantly contagious. After studying in Germany and the United States, Eisert worked as a lecturer at the Imperial College of London and is now a physics professor at the University of Potsdam.

The three researchers treat complex quantum systems as information-processing aggregates, examining them through the methods of computer science. At the same time, they apply the abstract concepts developed for quantum computing to concrete physical problems, such as those that crop up in the research on superconductive

substances. In both cases, the concept of information as it exists in its classical and quantum-mechanical form plays a central role.

The basic unit of classical information theory is the bit, which can have a value of 0 or 1. Larger amounts of information are represented by bit strings, which consist of sequences of zeros and ones (e.g. "0110101…"). Traditional computers are used to store and process such bit strings. "In a calculation, a sequence of zeros and ones are transformed into another sequence according to specific rules," explains Tobias Osborne in a soft-spoken voice. With his deliberate manner, the Australian researcher is able to convey even highly abstract concepts, using concrete examples as illustrations. After studying at the University of Queensland in Brisbane, Osborne went to Great Britain, enrolled in the postdoctoral program at Bristol University, and is now a lecturer at Royal Holloway, University of London.

The basic unit in quantum information theory is the "qubit" – short for quantum bit – which can occur in the basic state of (0) or (1). "Quantum mechanics tells us that a qubit can take on many more states," stresses Osborne. "In quantum-mechanical superposition, the qubit can also exist in other states, for example, (0) + (1) or (0) – (1)." In this case, the states of (0) and (1) exist simultaneously. Similarly, we can say that, in the state of (dead) + (alive), Schrödinger's cat is both dead and alive.

A qubit can be stored on an electron, which behaves like a tiny magnetic gyroscope. In a magnetic field, its angular momentum, or spin, can be along the field direction (state (0)) or along the opposite direction (state (1)). But the spin can have many other possible orientations, which correspond to differently weighted superpositions of (0) and (1).

While all forms of classical information are equal and can be converted from one form into another, quantum information is fundamentally different. Only in certain cases can classical information be converted into quantum information and vice versa. For instance, we can transform a classical bit with the value of 0 or 1 into a qubit by putting the qubit in a state of (0) or (1). In this case we can determine the qubit's state by taking a measurement – e.g. measuring the direction of the electron's spin – and thus convert back to bits.

However, if the qubit is an unknown superposition of (0) and (1), its state cannot be determined by a measurement. The measurement only leads to a random result: either 0 or 1. Since the unknown superposition state is destroyed by the measurement, quantum information is irretrievably lost when it is converted into classical information. "That's why quantum information is more powerful than classical information," emphasizes Jens Eisert.

Quantum computers aim to exploit the potential of quantum mechanics for data processing. "Like a traditional calculator, a quantum computer stores information with the help of particles," says Tobias Osborne. "However, in order to perform calculations, it lets the particles interact according to the laws of quantum mechanics." In the process, the computer shapes the

complex patterns of the qubits on the particles into new patterns. Several prototypical quantum computers exist today in laboratories around the world. In order to store qubits, they use atoms held in isolation, the spin of electrons, or other methods.

A quantum computer has not yet been built that is powerful enough to process hundreds of qubits, but studies have shown that such a machine, if equipped with the right "quantum algorithm," would be able to perform many operations much more quickly than an electron computer with a traditional computer program. These operations include breaking down multi-digit integers into factors like the ones required for special encrypting processes. A number of these operations can only be performed by a quantum computer.

In addition to the superposition of states, quantum physics presents us with an additional peculiarity that can be utilized for data processing: "entanglement." Although we cannot put the individual electron spin into the superposition state of (0) + (1), two spins can exist in an entangled state of (0,0) + (1,1). This is the equivalent of the macabre state (expressed as (alive, alive) + (dead, dead)) of two Schrödinger cats that are alive and dead at the same time.

"Entanglement makes quantum mechanics much more complex and richer than classical physics," says Ulrich Schollwöck, who heads the group of three quantum "mechanics" at the Wissenschaftskolleg and is the calming influence in the trio. After studying in Germany, Great Britain and France, Schollwöck worked, among other places, in Stuttgart and Aachen. He is currently a physics professor at Ludwig-Maximilians-Universität in Munich and investigates complex many-body quantum-mechanical systems.

How have he and his associates benefited from their stay at the Wissenschaftskolleg? "Beyond our work in physics, the constant interaction with philosophers and humanities scholars has enabled us to hone our conceptual capacities. Conversely, we were able to communicate just how much the conceptual work with quantum theory has evolved in recent years. This had largely gone unnoticed by people outside physics."

But back to quantum-mechanical entanglement: two qubits or other objects that are entangled in a quantum-mechanical sense need not be located in the same place but can exist, say, in Berlin or Brisbane. These qubits coordinate their behavior over long distances – an experimentally verified consequence of quantum physics that Albert Einstein was unable to reconcile with his local realist worldview. Addressing this point, Schollwöck says: "Most of the information in a quantum system cannot be collected locally, but is distributed over the entire system. As a result, when we describe such a system, the complexity of our description is heavily dependent on the degree of nonlocal entanglement."

Due to the superposition and entanglement of simple quantum states, even relatively simple systems of 1000 electrons can take on an enormous number of possible states – a number that far exceeds that of atoms in the universe. By way of illustration, we need only conceive

of the possible states of a many-body system as points that are equally distributed in an abstract "state space." If we put the system in an initial state in which its 1000 electrons spin in the same direction, the system will, to a certain degree, occupy some corner of the state space. How will it evolve?

"The number of quantum states that can be assumed by an object consisting of interacting particles is much, much smaller than the number of all possible states," says Jens Eisert. "The object does not move out of its small corner in the vast state space. The space comprising all possible states is an artifact of quantum theory. In fact, nature prefers to remain in the corner of the state space."

Jens Eisert has examined how this corner can be identified and how the dynamic development of a quantum system in this corner can be described in simplified terms. "If we know where the needle is in the haystack, it makes the search for it a whole lot easier." Furthermore, the simplified description of the dynamic of a quantum system can be utilized to simulate more efficiently the behavior of the system on a computer.

Tobias Osborne investigates how information spreads in complex quantum systems. "If we disrupt part of an object, information about this disruption must flow to another part of the object before the disruption is noticed there." Osborne has calculated how quickly information is able to spread in certain quantum systems. As long as the different parts of an object have not exchanged information, the object can be seen as consisting of several independent areas – which significantly reduces its complexity.

Disorder in a system can impede or entirely prevent the exchange of information. To illustrate this point, Tobias Osborne uses a pile of overhead projection transparencies as an example. Although we can see through a single transparency, if the pile is half an inch thick it will be nearly opaque and reflect the light just like a mirror. "A single transparency primarily reflects those waves of light where the thickness of the transparency is an integral multiple of the wavelength of the light. Because transparencies of different thickness are randomly distributed in the pile, every wave length will be reflected at some point or another and be kept from dispersing."

This phenomenon, known as "Anderson localization," also crops up in disorderly quantum systems, says Osborne. "As a result, the information has a difficult time spreading through the system. The system's different parts remain largely independent of each other, and the entire system can only assume a relatively simple quantum state with a low degree of complexity." In this case, too, the quantum system remains in the corner of the state space examined by Jens Eisert, whose behavior can be described in relatively simple terms.

These findings have practical consequences for Ulrich Schollwöck's work. Schollwöck studies quantum systems in the field of solid state physics, which covers magnetic materials and high-temperature superconductors in which electric current can flow without resistance. "The quantum systems that I'm interested in

are marked by an especially high degree of quantum mechanical entanglement. If you want to precisely calculate their physical properties, you would have to consider all the states within a vast and highly complex state space," explains Schollwöck. But this is virtually impossible. And in many cases it is also unnecessary – provided we are content with results that are "near-exact."

The behavior of several many-body systems from the field of solid state physics – in which the movements of electrons and their spin orientations are entangled in a complex manner – are not as complex as initially expected. They, too, remain in one small corner of the vast state space, so it should be possible to describe them in relatively simple terms. "We're looking for efficient calculation methods to determine the characteristics of such systems. The price we've paid for this is that our results are not exact. But by performing appropriately large computations, we can reduce the error as far as we want."

Using this method, it is possible to calculate the behavior of complex quantum systems on traditional computers; a quantum computer is unnecessary. But there are limits. Many complex quantum systems are so tightly entangled that traditional calculation methods are inadequate to deal with them. "Such systems are quantum computers themselves," notes Jens Eisert. "In a way, calculations on quantum computers and the efficient simulation of quantum systems on traditional computers are two sides of the same coin." That which cannot be simulated on a normal computer can perhaps be used as a quantum computer.

Nature, too, plays by the rules of the quantum mechanics game. And it, too, is incapable of using more than a tiny fraction of the enormous potential of quantum mechanics. Is nature more powerful than an equally complex quantum computer? Is it, in the end, a quantum computer itself? "We don't want to go that far," says Ulrich Schollwöck, smiling. "We don't want to annoy the philosophers at the Wissenschaftskolleg."

Letter from Berlin

Berlin Winter

Fellow 2009/2010

by Martin Mosebach

For many, this January and February were a "winter of discontent", especially in Berlin, where the city willingly abandoned itself to snowdrifts and crusts of ice, or at any rate put up no fights worth mentioning against it. Many broke their bones on the slick sidewalks, many souls turned gloomy in the long darkness. I'm almost embarrassed to have to admit that I enjoyed the Berlin winter to the fullest. I'm an adherent of extreme seasons, anyway; I find regions with an eternal spring uncongenial. To experience the tree in front of my window in the most widely disparate states – bare and in thick foliage, covered in blossoms or in snow – is consolation to me and gives me the feeling that something is going on in my life. I had to journey after the winter for so long; it showed itself only halfheartedly and indecisively in the lowlands, gray, dull, and moist, behaving in comparison with summer like a broken-down stage set just waiting to be smashed. And then the Engadine came to Berlin, white-blue and icy cold, transforming the city, which may have many hidden beauties, but which does not present itself as a beauty as a whole. Those who come from overpopulated western Germany enter a peculiarly sleepy calm in Berlin, anyway; the broad territories, which form not so much urban districts as city fragments, blurring apart, drifting alongside each other like ice floes, spread out around a center as empty as a desert. Those who are accustomed to grasping a city as a large organism have to come up with another image for Berlin. Berlin prepares itself for many kilometers, only to finally fall apart again before it has begun. It recalls certain overblown concert waltzes that send a colossal, expectations-increasing tararaboom ahead of a hit-parade melody; in the most favorable case, Berlin consists of such tararaboom preludes that are not always followed by the melody they emphatically herald. In the dense white of this winter, my frustration over this impalpability was simply snowed in; the driving snow turned Berlin completely into a no-man's land. The streets lay deserted, all sounds fell silent.

It was as if the whole world were a city devoid of people; it had something of the end of time about it. And in a present that peers apprehensively toward the future, the prospect of such an end of time is consoling in its peace and its downy, cleanly, ice-cold gentleness. In the Mausoleum of the Charlottenburger Schlosspark, we stood before the marble image of Queen Luise fallen into her

sleep of death. The Carrara stone, pleasantly cool even in summer, was now deep-frozen; the lightly, probably even transparently clothed Queen had become a goddess of cold, a Snow Queen with no signs of royalty except a small diadem. The shroud had sunk down upon her like a blanket of new snow; the little feet in the pointed sandals turned into abstract, spiky elevations, as if in reality two sugar loaves stood beside each other beneath the batiste – revealing once again that the true inventors of Surrealism were the artists of Neoclassicism.

And so it was not possible for us to take part in the public indignation over the fact that the communal administration made no efforts to remove the white dress of winter and the white empire of the Carrara Queen, but may even have reinforced them instead. The snowplows primarily assumed the task of walling in the cars parked at the side of the street with ramparts of snow that rapidly froze as hard as stone, since it was hardly advisable to skate around with them anyway. Weren't all voices, even the most agitated ones in public life, somewhat dampened in these weeks of snow? Wasn't a world entirely without this "public life" suddenly imaginable? That's the charm of a utopia – when it unexpectedly displays itself as reality for a brief moment. And that's why I'd like to conclude my letter from Berlin with a poem that encompasses most strikingly the "eternity" quality of the most delicious moments of this winter. It is by Ror Wolf, the most important living German poet, and is titled "Weather Conditions":

"It snows, then the rain falls down, / then it snows, it rains and snows, / then it rains the whole time, / it rains and then it snows again."

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