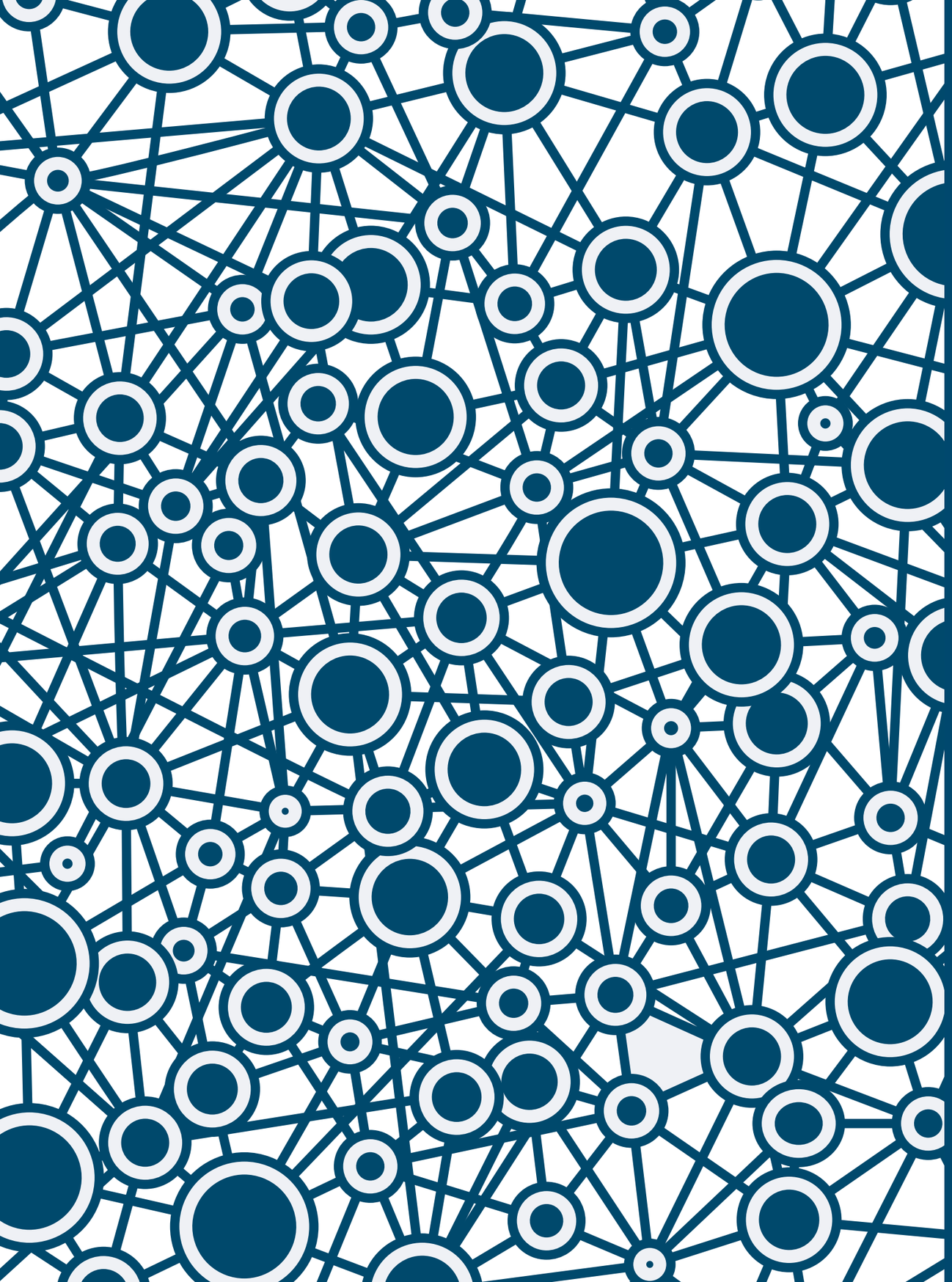
The Idea Factory

Complexity Science Hub Vienna: The First Five Years



COMPLEXITY
SCIENCE
HUB
VIENNA

Fore words

Challenge Accepted

One's own present has always been considered as particularly complex. This was no different 100 or 200 years ago than it is today. However, a decisive difference to earlier centuries is that the amount of information and its global availability have increased to an unimagined extent. This enables temporally diagnostic linkages that have actually never been possible in this form before.

The Complexity Science Hub Vienna has taken up this challenge and managed in a very short time to become an important and highly respected player in this new field of research. It was able to quickly prove that it is not only the amount of data, but also the manner of questioning and the form of the respective links that are crucial for generating insights. Without committing itself to the dream (or nightmare) of the "transparent human being," the CSH has thus become, within just five years, a contact point for coping with a confusing present—such as the corona pandemic just now.

I wish all those involved—and they are certainly not the least brainy in the country—continued success, much pleasure in researching our times and, above all, one thing: planning security.

All the best,

Alexander Van der Bellen
Austrian Federal President

An Institution Whose Time Has Come

The age of an institution tells us little about how it has matured, nor about the impact it had in the meantime. This holds even more for a research institution that follows a moving target by focusing on the dynamics of complex systems that cover a wide range of natural phenomena, human activities, and their mutual interaction—be it the sustainability crisis, the banking system and financial markets, healthcare or how the dynamics of an economy can be tracked in a 1:1 data-based model. With new challenges continuing to arise, the Complexity Science Hub Vienna (CSH) identifies systemic risks and the tipping points that may precede, or prevent, the collapse of an entire system. By definition, this is work in progress, yet it generates insights and empirically validated knowledge that cut across many domains by following the interconnecting networks that constitute complex adaptive systems.

The fifth anniversary of the CSH presents a welcome occasion to recall the raison d'être of the Hub and to assess why it is needed, perhaps more than ever. The Hub is the only institution in Austria with the competence to systematically utilize Big Data for a better understanding of complex systems and the ability to translate this knowledge into new dimensions of evidence-based policy measures which, in turn, can be simulated in order to detect unintended consequences. It explores the potential to participatively design simulation models and to collect, monitor, and store data in ways that make them interoperable for trust-based stakeholders. In a world that is becoming ever more dependent on data, the CSH is a pioneering institution, experimenting with new ways of tackling complex problems that have a huge bearing on the future of our societies.

In this endeavor it is not alone. The CSH is part of a lively and global network of similar institutions, such as the Santa Fe Institute in New Mexico and several others. It has quickly gained visibility and is now regarded as one of the exciting and innovative places attracting young researchers to meet and exchange ideas with Senior Scientists and PostDocs. Its scientific appeal, aided by the scientific profile of Stefan Thurner, and its outreach capacity are extended through the External Faculty. An International Scientific Advisory Board which I have the honor to chair regularly discusses and advises the Hub in all scientifically and strategically relevant matters.

From the beginning, the Hub was conceived to also build new forms of cooperation among universities and other research institutions, thus opening the possibility of some of the best and most enterprising students to engage in exchange with leading international figures. The growing number of institutions that together support the Hub confirms that new transdisciplinary modes of working across academic disciplines and institutional domains are emerging, foreshadowing further changes in the organization of science and its greater openness towards society that are currently under way.

An additional reason why the CSH is needed was highlighted during the COVID-19 pandemic. The Viennese Hub demonstrated admirable agility, high professional competence, and the ability to meet expectations coming from decision-makers and the public. By developing a strategic and coherent "package" based on the repurposing of team members' efforts, the CSH excelled in providing data-based answers to the many questions that arose during the pandemic. Whatever we make of the many lessons the pandemic holds, the CSH has earned its place as one of the scientific institutions that is able to respond to societal needs in ways that are at the forefront of where science can lead.

In this sense, it is an institution whose time to fully realize its potential has come.

Helga Nowotny
Chair, CSH Science Advisory Board

On June 16, 2020, we had the honor of welcoming the Austrian Federal President Alexander Van der Bellen at the Hub. From left to right (front): Stefan Thurner, Alexander Van der Bellen, Helga Nowotny. From left to right (background): Vito Servedio, Peter Klimek, Hannah Metzler, Johannes Sorger.

Three Wishes

The Hub is turning five. Hard to believe how fast these years have passed. When we moved in, there were just three of us sitting in the vast rooms of our Palais... now we are bursting at the seams.

Along with the increasing numbers of people and talents, our topics, interests, and expertise are also evolving. Here are my three personal wishes in what directions this evolution should go in the coming years:

It is conceivable that many cultural achievements of our time—science included—will be judged by the extent to which they contributed to the successful green transition. By green transition I mean those collective global efforts necessary to manage the climate crisis without destroying civil society and its egalitarian values of freedom and solidarity in the process. Wish number one: I would like to see the Complexity Science Hub Vienna as an institution that fundamentally subscribes to the necessity of bringing about a successful green transition.

Complexity science offers a new worldview or paradigm that sees the world as the sum of its networks. From this perspective, the green transition is nothing but a reorganization of socio-economic networks to massively reduce GHG emissions without destroying social coherence. For apparent reasons, these problems currently seem hard or even impossible to solve at the same time. To find solutions nevertheless, we need people who can potentially do that: "green transitioneers." Wish number two: I would like to see the CSH as an institution that produces such people, an institution that attracts those creative scientists of all ages and backgrounds who want to make a change—through the beauty and power of contemporary, forward-looking science.

The green transition needs science, it needs data, and it must confront the issue of complexity: the fact that most things in the world are essentially driven by dynamic networks. Complexity science teaches us how these work in the various contexts of nature, society, ecology, economy, infrastructure, etc., and how these are interlinked. In combination with data and novel ways to generate meaning from them, for the first time in history it becomes possible to address complex systems scientifically. And with such an understanding, maybe, doors might finally open towards a management of complexity.

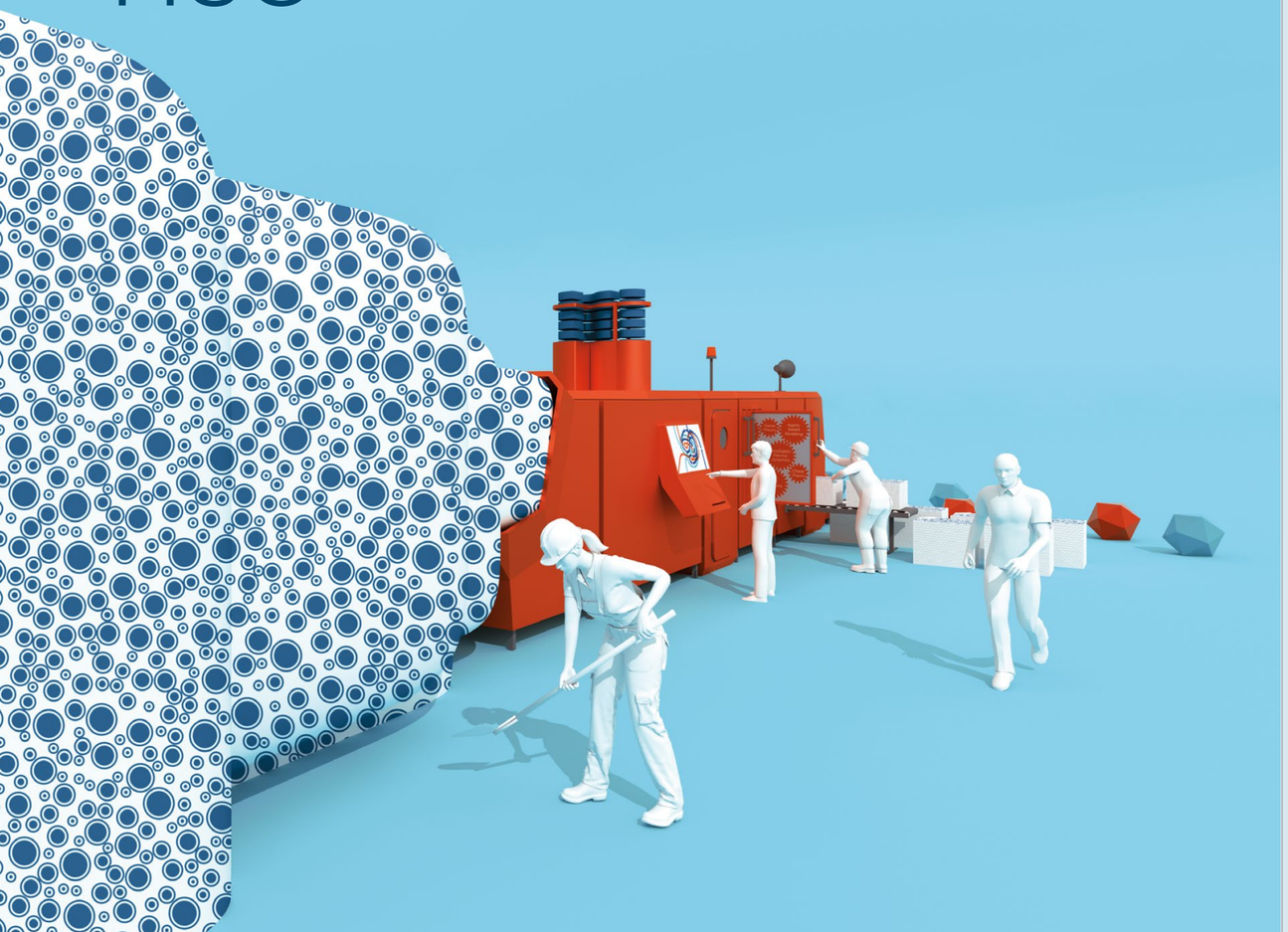
Efficient management and solutions will be needed—solutions that work. And this is my wish number three: I would like to see the CSH as an institution that creates scientific knowledge which builds a base allowing us to eventually make evidence-based policy decisions—transparently, rationally, sustainably, and fairly.

I am deeply thankful to be part of this journey with the scientists and the immensely effective admin team at the Hub. And I am excited about the discoveries we will make together.

Stefan Thurner
CSH President

Where Big Data Starts to Make Sense

Its research fields and subjects; its methods and data used; the multitude of scientific backgrounds of its people; the broad range of findings: The Complexity Science Hub Vienna is a whole uni-verse(ity) in one small place.



Welcome!

Welcome, everybody, to the Complexity Science Hub Vienna | the CSH | "the Hub": A place where, as we believe, Big Data starts to make sense!

Big Data

In one way or the other, science has always been data-driven. How good, then, that we have data in unprecedented quantity and (sometimes) quality today, zillions of bits and bytes, collected about everything and anywhere in the world… don't you agree?

Data, Big Data: the "gold of the 21st century!"

Yet, here is the drawback: Data alone will not enlighten us. Although simple if–then correlations drawn from observations might well create Eureka effects, the challenges humankind faces today, some of them probably the biggest threats in Homines sapientes' short history, require a totally new approach to science.

Above all, we need to accept that addressing the overwhelmingly intertwined problems of our time requires nothing less than to face, and to embrace, the governing principle of about anything that happens and moves on this planet: complexity.

To address complexity, we need complexity science. This is where the Hub enters the scene.

BD for Big Questions

With the help of large, comprehensive datasets, the CSH is willing to approach big, that is, complex questions: What are the effects of financial turbulences on society? How will urbanization change the economy/democracy/our need for resources? How will digitization/the growing number of natural disasters/fake news/migration/a pandemic influence humanistic values/economies/medicine? And the perhaps biggest of all BQs: How can our species finally learn to manage the complexity around it in an ecologically, socially, and economically sound way?

BD+BQ need Big Theory

If we are aiming to gain such far-reaching insights into the networks (of networks), to gain insights into systemic risks, resilience, tipping points, or the efficiency of complex systems—into all these Big Qs that were unintelligible only a few decades ago—simplification, the means of choice in science for centuries, will no longer do.

BD+BQs need Big Theory!

The science of complex systems provides us with the necessary new mathematical and statistical tools—some of them are being developed at the Hub.

BD+BQ+BT won't work without Big Talent

To come that far, we need people who have rigorous training in a relevant discipline, as well as quantitative, mathematical, modelling, and data expertise. The limited number of such people is a major (and worldwide!) bottleneck. At the CSH, we are therefore aiming not only to attract, but also to train young and highly talented people to become such experts: true "masters of Big Data."

Many scientists working at the Hub are skilled in more than one discipline (they certainly work in more than one). Such a broad knowledge base facilitates collaboration across disciplines inside the house and beyond, and forms the basis for developing discipline-crossing ideas in discipline-crossing workshops and conferences in order to eventually push disciplinary boundaries. "Only scientific excellence will bring us forward," Stefan Thurner, CSH co-founder and President, once said. "The Hub will only be successful if we are able to attract, to train, and to work together with the most creative, sparkling, brilliant people; to leave the beaten tracks together, daring to enter new scientific grounds."

BD+BQ+BT2→ Findings for the benefit of society

With all these big requirements fulfilled, the Hub is hopeful to reach a deeper understanding of complex systems and their networks (of networks). We build agent-based models to simulate reactions and (unintended) consequences of interventions without the immense costs of real-life trial and error, to identify a system's tipping points, or to specify requirements for alternative pathways… in other words: to generate an impact and a benefit for society.

The CSH Idea Factory

Simple principles of complex knowledge production

BIG DATA

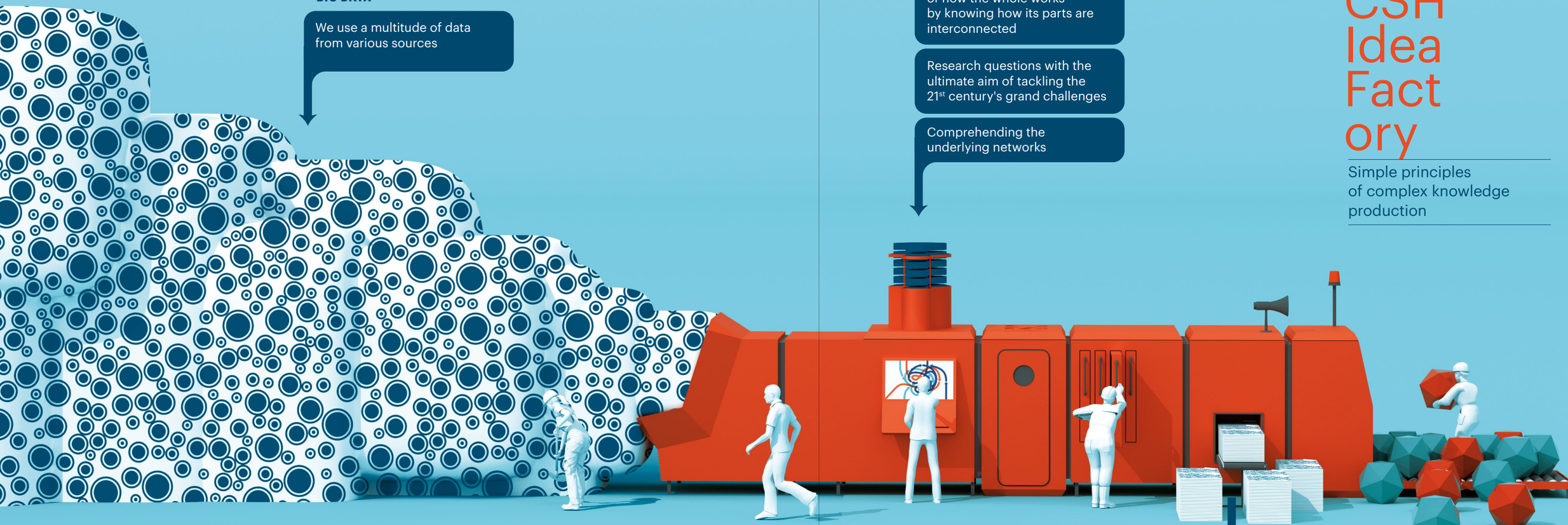
We use a multitude of data from various sources

BIG QUESTIONS

Towards an understanding of how the whole works by knowing how its parts are interconnected

Research questions with the ultimate aim of tackling the 21st century's grand challenges

Comprehending the underlying networks



BIG TALENT

We hire and educate high potential (young) scientists

BIG THEORY

We use and develop new mathematics and statistics to better deal with Big Data and complex systems

FINDINGS

We gain scientific knowledge, new tools and methods, agent-based models for a deeper understanding of complex systems and their properties

Data-driven approaches

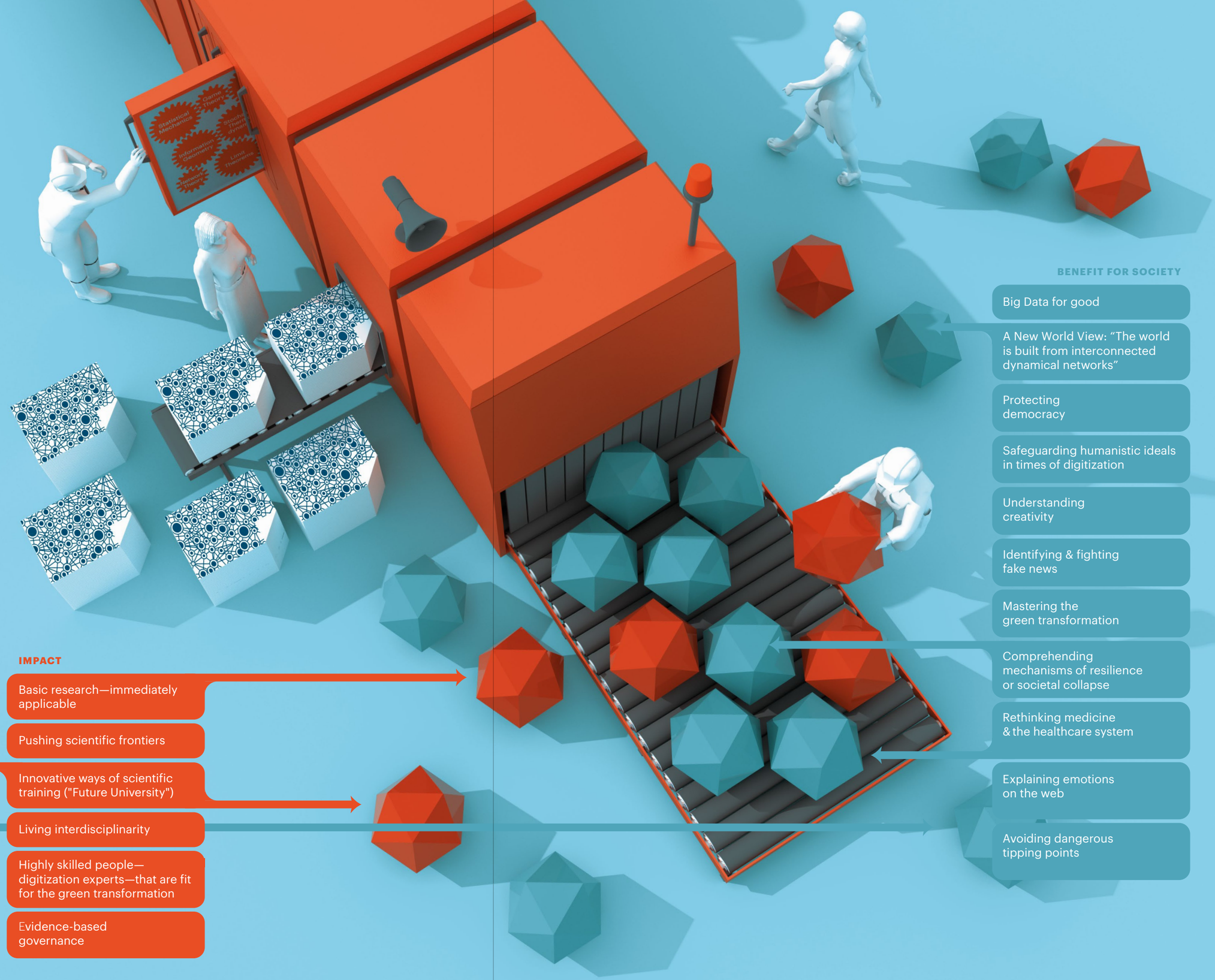
Novel perspectives resulting from our interdisciplinary mindset and institutional design

Thinking in “ands”

IMPACT

BENEFIT FOR SOCIETY

Creating Impact & Benefit for Society



IMPACT

- Basic research—immediately applicable
- Pushing scientific frontiers
- Innovative ways of scientific training ("Future University")
- Living interdisciplinarity
- Highly skilled people—digitization experts—that are fit for the green transformation
- Evidence-based governance

BENEFIT FOR SOCIETY

- Big Data for good
- A New World View: "The world is built from interconnected dynamical networks"
- Protecting democracy
- Safeguarding humanistic ideals in times of digitization
- Understanding creativity
- Identifying & fighting fake news
- Mastering the green transformation
- Comprehending mechanisms of resilience or societal collapse
- Rethinking medicine & the healthcare system
- Explaining emotions on the web
- Avoiding dangerous tipping points

Much Ado About... Comp lexity

On the following pages you will find what is driving us: our questions and methods, our research fields and topics.

Note: The way our fields are depicted here is just one possibility of arranging all the countless questions, projects and subprojects, multidimensional co-operation, transdisciplinary group work and working groups, all the many “this and that” approaches and findings that make our institution so distinctive.

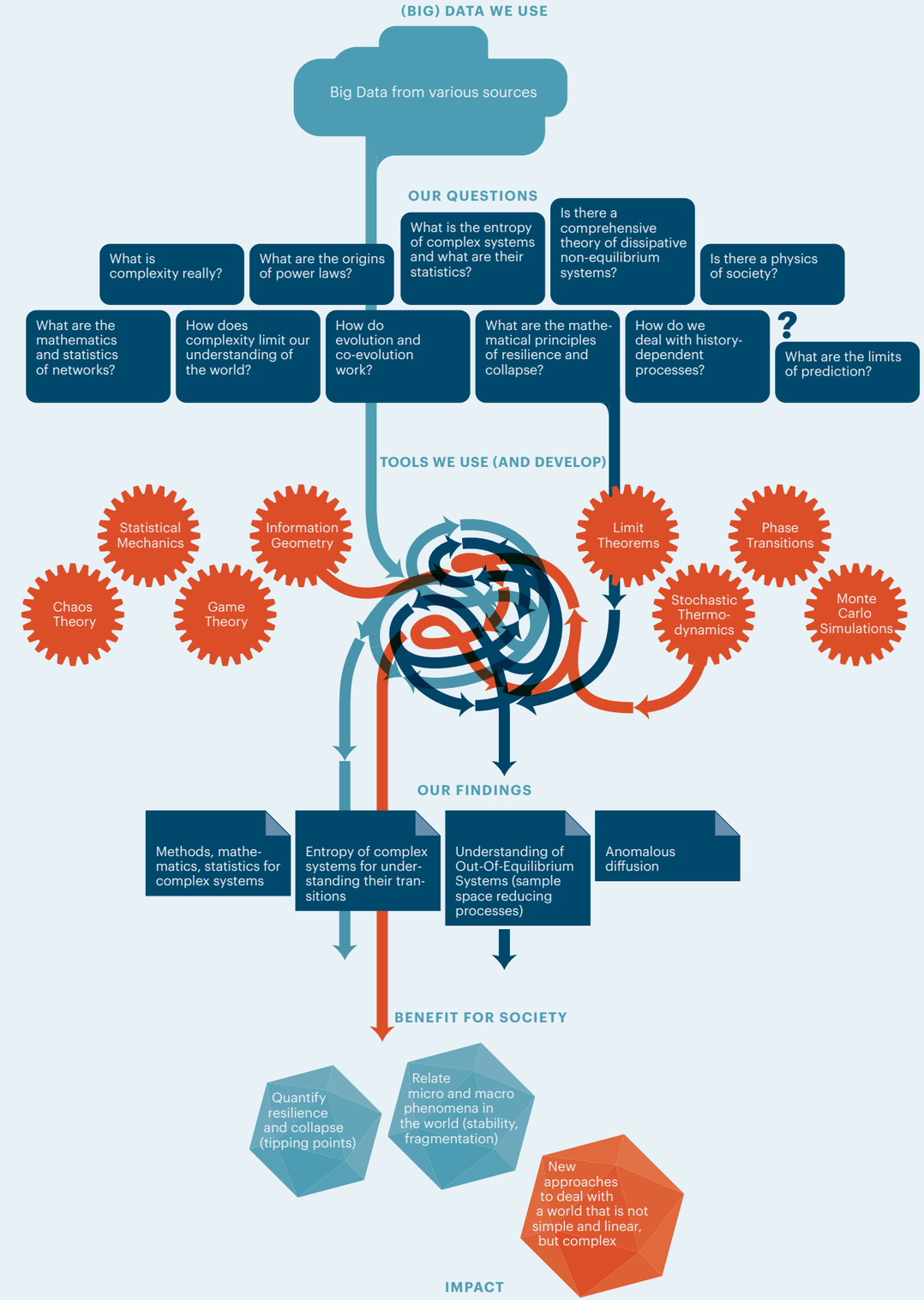
SELECTED RESEARCH FINDINGS

Foundations

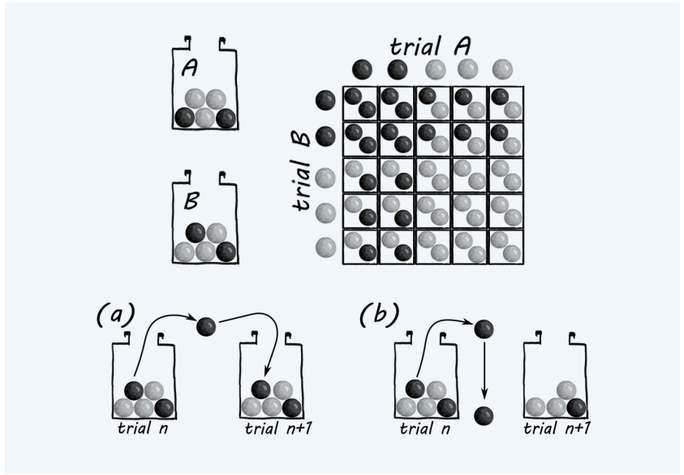
The new mathematics and statistics for dealing with complex systems that our theoreticians develop are the groundwork for much that is going on at the Hub.

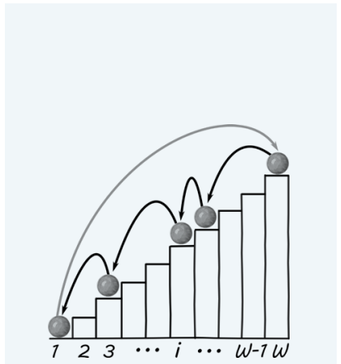
We are convinced: To deal with the great challenges humanity is facing we not only need data. We also need new approaches to handle Big Data in a way that makes more sense for a world that is not linear and simple, but complex. It is the core business of complexity science to develop such new tools and methods. We call those our "Foundations"—our "Big Theory."

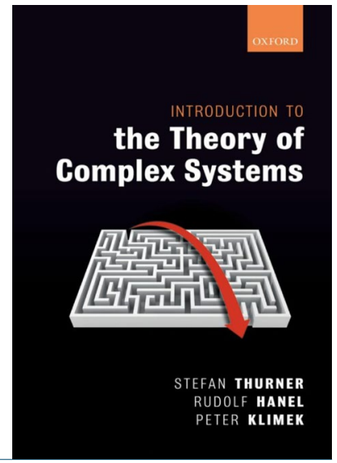
Although they are quite hard to explain to a world outside of complexity science and therefore maybe not as present in our news (or in the media) as other, catchier findings, foundations of complex systems are what we often need and what we use to approach the different research questions presented on the following pages, be it medical treatments or collapsing financial markets, economic forecasting or Twitter analyses, questions of city design or fairness in algorithms.



A Book for Complex Beginners







Introduction to the Theory of Complex Systems. Most of the images in this textbook were hand-drawn by Hub theoretician Rudi Hanel, one of the authors.

Three Hub researchers not only offer students an overview for their start in the field. In their textbook *Introduction to the Theory of Complex Systems*, Stefan Thurner, Rudolf Hanel, and Peter Klimek also propose a novel—and widely acknowledged—definition of complex systems as "adaptive, co-evolving algorithms."

Complexity is a tough nut for scientists to crack. But Big Data changes the picture. For the first time in history, complex systems can be approached empirically, thanks to the exponential rise of data gathering devices and, therefore, data.

Data is the reason why the field became so interesting for physicists, social scientists, mathematicians, and biologists alike. Thanks to data, they are able to develop and test models, pursue experiments, verify, or falsify their hypotheses with the aim to predict and eventually manage complex systems. "We are the folks who keep on trying until we have a solution," Stefan claims. "Physicists explained gases, opened up fields like astronomy or chemistry. Now we are up to understanding the much more complicated world of complexity."

MANY SCIENCE STUDENTS WILL BECOME DATA ANALYSTS

Complexity science has been prospering and progressing since the turn of the millennium. This has led to a rise in popularity among students, too: Their numbers are constantly rising. The available textbooks, the Hub authors found, did not keep pace with this growing interest. "Although some of them are considered classics, the existing introductions to complex systems, network theory, agent-based models, and so on, represented 20th century knowledge," says Rudi.

Their *Introduction to the Theory of Complex Systems*, published by Oxford University Press in 2018, now gives an overview of the field and provides the up-to-date mathematical startegies to deal with data and with complex systems in particular. This knowledge will be in high demand in the future, since "most young people entering science today will later work as data analysts," Peter points out.

Statistics Needs Improvement

COMPLEX SYSTEMS WORK LIKE ALGORITHMS

The book is an effort to unify the many loose ends from theories and approaches that were developed (but to date not connected) by a whole generation of complexity scientists. Stefan, Rudi, and Peter propose nothing less than a "coherent framework," as they call it, a simple, comprehensive definition to approach and describe nearly all complex systems: "Complex systems work like adaptive, co-evolving algorithms," they say.

This definition, the authors believe, will enable future complexity scientists to deal with almost all statistical patterns that have been observed in a multitude of complex systems across domains.

S. Thurner, R. Hanel, P. Klimek, ***Introduction to the Theory of Complex Systems***, Oxford University Press (2018)

(... but the right one...). In science it is essential to use data without massively wrong values, so-called "outliers" obtained from wrong measurements. CSH researcher Jan Korbel developed a method to correct these errors.

Real data can be erroneous, and if correct anomalous measurements are omitted, the results are flawed. Scientists therefore want to correct wrong data. "The problem is: You very often don't know the reason for an outlier," says Jan, one of the Hub's dedicated theoreticians.

"It is generally quite difficult to distinguish between correct data and outliers," he explains. Take temperature measurements as an example. If weeks of heat are interrupted by a single exceptionally cold day, the outlier could be the product of a broken meter. But it could just as well be another sign of the growing number of extreme weather events that humans produce by incessantly heating up the planet—quite the opposite message.

A SOLUTION TO CORRECT OUTLIERS

Statisticians come up with different solutions to deal with the anything-but-trivial problem appearing in complex systems. Jan and his Turkish colleague Mehmet N. Çankaya introduced a method based on robust statistics. "To put it in simple words, we average the underlying distribution and the outliers," Jan explains the, as he puts it, "quite nice" statistical innovation.

They tested the concept with weather data from Grytviken, a small settlement on the island of South Georgia, not far from Tierra del Fuego and Antarctica, of which they knew the reason for the temperature spikes. They contaminated the long-term measurements with outliers, corresponding to recent extremely warm temperatures.

Their method proved to be successful. According to the researchers, the model produced more robust results on the presence of outliers than other approaches.

J. Korbel, M. Çankaya, **Least informative distributions in maximum q-log-likelihood estimation**, *Physica A: Statistical Mechanics and its Applications* Vol 509 (2018) 140–150

SELECTED RESEARCH FINDINGS

Medicine & Health care

To generate meaningful knowledge from Big Medical Data, we need new mathematical and statistical methods. Hub scientists are developing new ways of approaching medicine as a data-driven science of dynamic, co-evolving, generalized networks.

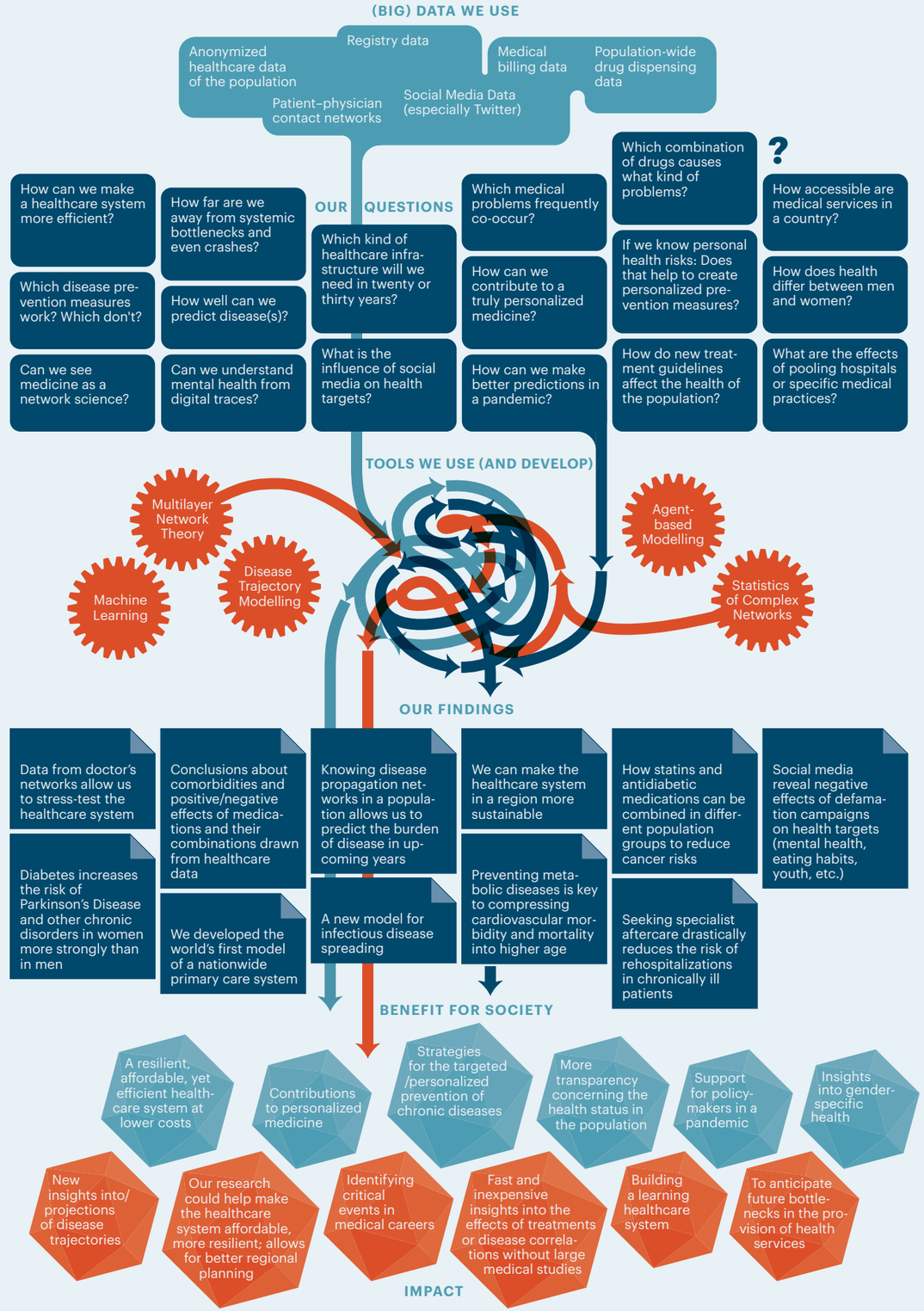
Like everywhere, the healthcare system and medicine are being gripped by the explosively increasing availability of huge amounts of data. Every doctor's visit, every prescription, every hospital stay leaves digital fingerprints which in sum provide a snapshot of all medical services and the health status of almost all people in a country. With a new generation of mathematical and computational models, such datasets will reveal entirely new insights.

The use of Hub research in the health complex is twofold. On the one hand, we look at the healthcare system as a whole: In the world's first model of a nationwide healthcare system, developed at the Hub, every patient, doctor, pharmacy, and hospital is represented by an anonymous avatar. Changes in the health of the patient's avatars, medical contacts, or hospital stays are formulated on the basis of concrete observations in a large dataset of medical billing data and can subsequently be modeled in various ways.

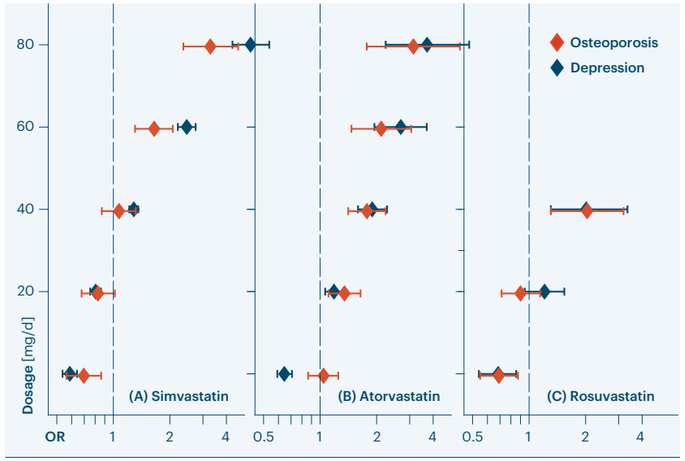
The model provides answers to questions like how many intensive care beds or general practitioners are needed when and where, or how far we are away from systemic bottlenecks and even crashes. Once we have identified the strengths and weaknesses of the system, we can make proposals to redesign it in a more efficient way.

Our second focus is to gain insights into individual disease trajectories describing how patients accumulate diseases and chronic conditions as they age. Knowing these trajectories and the health status of the entire population allows the development of the burden of disease in a country, as well as the future need for medical services to be accurately forecasted. We also hope to take a deeper look at individual health risks—basic research for the personalized medicine everybody is talking about.

Thirdly, Hub researchers are tracking and investigating the traces of emotional well-being (or not-so-well-being) in digital environments like social media.



Statin Use & Disease Risk



Dosage dependency of the statin–osteoporosis association in three commonly prescribed statins. A low dosage of simvastatin and rosuvastatin can be related to decreased osteoporosis risks, as indicated by the bars left of the cut-off line of 1. The probability for a diagnosis with osteoporosis increases significantly with high-dose treatment for all three statins.

At low doses, statins could protect against bone resorption. But the higher the dosage of cholesterol-lowering drugs, the greater the probability of osteoporosis, an analysis of millions of patient data shows. The same correlation appears for statin use and depression.

Statins are among the most prescribed drugs worldwide. They inhibit the synthesis of cholesterol from the liver, leading to decreases in blood cholesterol and cardiovascular risks. However, cholesterol is crucial for many processes in the body. Could an aggressive statin therapy not have undesirable side effects? A team of scientists from the Medical University of Vienna (MedUni) and the Hub are in search of clues.

"Cholesterol is a basic building block for the production of sex hormones such as estradiol and testosterone," says Alexandra Kautzky-Willer, an endocrinologist from the MedUni and a frequent Hub research partner. "We know, for instance, that low concentrations of sex hormones—especially the drop in estrogen levels during menopause—are the main cause for the increase of osteoporosis in women. There is a similar relationship between bone density and testosterone." In a study, the scientists investigated whether the inhibition of cholesterol production by statins could have side effects on bone formation and whether there could be a dose-response relationship.

THE HIGHER THE DOSAGE, THE STRONGER THE EFFECT

The team used a database with health data of more than 7.9 million Austrians from 2006 and 2007. "We filtered out those who regularly took statins for at least one year," states Caspar Matzhold, one of our young scientists who carried out the processing and statistical analysis in the statin studies. He also calculated the daily dosage of statins and formed different dosage groups.

In a next step, the team looked for osteoporosis diagnoses. What it found was a clear correlation between the dosage of statins and the frequency of osteoporosis. In up to 10 milligrams (the lower dose groups) there were fewer osteoporosis cases than one would expect. Yet, with doses of 20 milligrams and more, the tide seemed to turn: The higher the statin dosage, the stronger the negative effects were. The correlation appeared in both sexes.

STATINS AND DEPRESSION

It was the first time that connections between the dosage of cholesterol-lowering drugs and an osteoporosis diagnosis was established. In another analysis of the same dataset, the team found a very similar dose-response correlation, this time between statins and depressions. While patients on low-dose statins had a slightly lower depression risk than patients without statin medication, the prescription of higher and high dose statins went along with a risk multiplication.

"These studies clearly show how helpful large datasets can be to examine open medical questions. The combination of medical expertise with our knowledge in Big Data analysis makes completely new insights possible," says co-author Peter Klimek (CSH & MedUni). "Given the wide use of statins, both findings are highly relevant for clinical routines across medical disciplines," Peter concludes.

M. Leutner, et al., **Diagnosis of osteoporosis in statin-treated patients is dose-dependent**, *Annals of the Rheumatic Diseases* 78 (2019) 1706–1711

M. Leutner, et al., **Major Depressive Disorder (MDD) and Antidepressant Medication Are Overrepresented in High-Dose Statin Treatment**, *Frontiers in Medicine* 8 (2021) 608083

Contagious Suicides

A spike in suicides after *13 Reasons Why* went on the air. Panels A and B show suicides among young males in the US in 2016 and 2017, panels C and D, suicides among young females. The panels on the left show that increases in the observed values from April to June 2017 are outside the 95% confidence bands of the forecasts of models that were fitted to the pre–April 2017 data only. The panels on the right show the effect of modelling the April 2017 increase with a discrete pulse in the full data.

A study pursued with Hub participation raises concerns about the Netflix teenage drama *13 Reasons Why*.

Knowing that young people are especially susceptible to so-called copycat suicides, youth psychiatrists were highly alarmed when *13 Reasons Why* went on the air in April 2017. The series describes why high school student Hannah Baker felt forced to commit suicide, and it shows, in explicit pictures, how she puts an end to her life. The story addresses problems like bullying, gossip, or sexual assault and was exceptionally successful among adolescents. According to Netflix, *13 Reasons Why* was the third most binge-watched series in 2017.

Suicide prevention expert Thomas Niederkrotenthaler from the Medical University of Vienna, who also belongs to the CSH Associate Faculty, was an early critic of the drama. He asked Hub scientist David Garcia to carry out a data analysis to check a possible association between the release of the show and teenage suicides. "Netflix does not share viewership data, so we did an extensive social media search," David explains. "References to the show on Twitter and Instagram are a good proxy to the amount of attention the show received."

The team found more than 1.4 million tweets by more than 870,000 users for the period of April 1 to June 30, 2017. Instagram produced more than 26,000 posts by 7,875 influencers. The referrals peaked in April of that year. "There was no more social media attention for the drama after June. Therefore, we defined the exposure window as April to June 2017," David says.

22 PERCENT MORE FATAL CASES IN GIRLS

When the scientists matched official suicide numbers with this peak exposure, they found an increase in suicides in the age group of 10 to 19 years—the target group of the show. There was no rise in other age groups. In boys, the rise was 12 percent, in females, almost 22 percent. This did not surprise the scientists, as the main character of the show is a young woman.

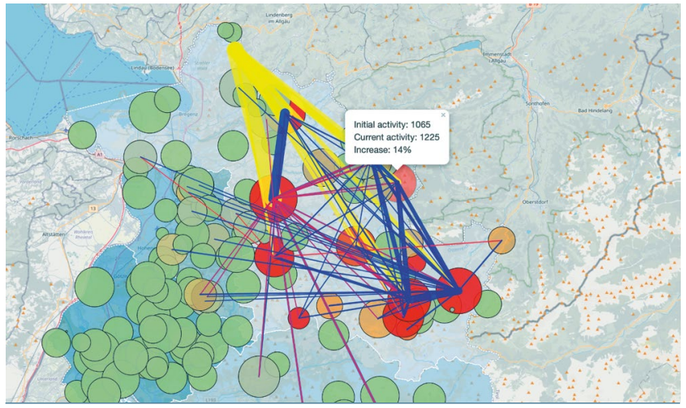
Of course, the researchers cannot know for sure if it was the drama that caused the increase. But as they know that an explicit showing of suicides in mass media provokes copycat suicides, that adolescents are highly susceptible to their peers, that the show is exceptionally popular among teenagers, and that the drama does not offer other solutions to Hannah's experience of bullying and sexual harassment than a suicide, it did not seem far-fetched to connect the show with the suicide spike.

Consequently, the study, which got worldwide attention, called for the entertainment industry to be much more cautious with this highly sensitive topic.

Netflix eventually added cautionary advisories and a helpline, and removed the drastic suicide scene. In some countries, the show has an age rating of 16+.

T. Niederkrotenthaler, S. Stack, B. Till, M. Sinyor, J. Pirkis, D. Garcia, I. Rockett, U. Tran, **Association of Increased Youth Suicides in the United States With Release of *13 Reasons Why***, *JAMA Psychiatry* 76 (9) (2019) 933–940

Stress Test for the Healthcare System



Simulation makes patient flows visible An interactive simulation, programmed by CSH visualization expert Johannes Sorger, illustrates the network dynamics in the Austrian province of Vorarlberg. Doctors and patients were replaced 1:1 by anonymous avatars. When single doctors are clicked away, the model shows where their patient avatars are moving on to.

How important is a doctor for the functioning of primary care in a region? How many doctors' retirements can the system absorb? Questions like these are driving stakeholders in the healthcare system. The Hub could help: In 2019, it introduced a method to infer the system's resilience in real time from its doctors' networks.

Based on data of patient flows between doctors in regional physician networks, Hub scientists built a 1:1 computer model of the Austrian healthcare system. Usually, the number of physicians in relation to the population—called "physician density"—is used as an indicator for the quality of healthcare. Yet, this indicator assumes that all physicians are equally accessible and equally important for all patients. "We found that this is not the case," says CSH's Peter Klimek. "Physicians and their patients form networks. With the same physician density, these networks can either be resilient or prone to collapse—or something in between."

The scientists used a dataset with all Austrian physicians and patient streams from 2006 and 2007 to create the network. Resident physicians are the nodes, connected to each other by their patients. "We were surprised at how closely connected and regionally focused the networks of patient flows are," mentions Peter. They called this "patient sharing."

Patient sharing becomes relevant as soon as a doctor's office closes. The data show that more than 80 percent of all patients choose physicians with whom they have previously had contact for their further medical care. Knowing that, the researchers were able to calculate with high accuracy where patients of a particular doctor will turn after the doctor's retirement.

HOW GOOD IS THE SYSTEM IN ABSORBING SHOCKS?

A resilient healthcare system will recover quickly and fully from such "shocks." However, if too many or particularly important doctors are lost at a time, for instance, due to a retirement "wave," this can overstrain the system. "Our simulation shows the critical point at which the system's ability to absorb additional patients or compensate for lost doctors collapses," states Donald 'Ruggiero' Lo Sardo, who worked on the simulation as part of his PhD thesis. "Thanks to our model, we know how many and which doctors can be removed from the system without problems," Ruggiero adds. "We can thus say how resilient the healthcare system is in a certain region, and we can determine how relevant each avatar is to the stability of the regional network."

For example, doctors with particularly large numbers of patients and good accessibility within the doctors' network lend stability to the system. Poorly networked doctors, on the other hand, will more likely weaken it.

The model provides stakeholders in the healthcare sector with a tool that allows (personnel) decisions and their effects to be tested beforehand. The scientists emphasize that the new method could also be extended to diverse scenarios, such as the outbreak of an epidemic, or a natural disaster with many casualties. "With up-to-date data, we can make valid assertions about the resilience of different subsystems in healthcare," maintains Peter. This knowledge facilitates planning and improves medical care. "As soon as people in charge know the systemically relevant doctors in a region, they can make the system more resilient by either trying to retain those doctors or to adequately refill their positions after they leave."

D. Lo Sardo, S. Thurner, J. Sorger, G. Duftschmid, G. Endel, P. Klimek, **Quantification of the resilience of primary care networks by stress-testing the health-care system**, *PNAS* 116 (48) (2019) 23930–23935

The Digital Cow

The COMET project *D4Dairy* makes use of Big Data generated in Austrian diary farms to gain insights for breeding, farming practices—and very likely for human health, too.

The amount of medical data is not only exploding for the homo sapiens. Dairy farmers, for instance, generate heaps of data, ranging from the health status of their cattle to their reproduction, milk quality, feeding information, environmental factors in stables, or the genome sequences of thousands of dairy cows. However, complaints were mounting that the data flood couldn't be utilized in a sensible way or that farmers were suffering generally from information overload. A large project supported by the Austrian Research Promotion Agency (FFG), carrying the beautiful acronym D4Dairy (Digitalisation, Data integration, Detection and Decision support in Dairying), addresses this issue.

D4Dairy, which started in late 2018, connects dozens of partners from agricultural organizations and farmers, through industry and smaller-sized enterprises, down to scientific institutions. The Hub is responsible for data integration—under the lead of CSH scientist Olga Saukh—and data analysis (Peter Klimek's team). "The data gathering systems in use are not plug 'n' play," says Olga. "We have to integrate the data for further use, check for monocompliance, calibrate, and structure the data gaining processes." Olga also expands the data collection to cover specific research questions defined by Peter and colleagues and is working on replacing punctual measurements with constant data streams.

FOR THE WELL-BEING OF COWS—AND HUMANS

Peter, for his part, is "happy about a new dimension of medical data analysis. Such comprehensive datasets, however, are still missing for humans." One reason is data security concerns—a minor problem among milk cows…

While most output of D4Dairy will lead to improvements in the health and well-being of milk cows, Peter sees the project from a broader—a complexity scientist's—perspective: He wants to come to a better understanding of the interplay between nature and nurture in general. "Big Data," he says, "will help us disentangle genetic, environmental, and individual factors that contribute to either health or disease in a subject. As we humans share 83 percent of our genes with cows, the methods and prognostic models we are developing and testing in D4Dairy will be applicable to us as well."

SELECTED RESEARCH FINDINGS

Corona—A Proof of Concept

The onset of the COVID-19 pandemic proved to be a moment of truth for the Hub. Could its data-driven methods be of use in a state of emergency?

Could its understanding of complex networks help combat problems arising from worldwide systemic disturbances? Could CSH's research be directly applied to a real-world crisis? As the following pages show: it could.

Several days before Austria's first lockdown in March 2020, the CSH had been approached by representatives of the Future Operations Clearing Board of the Austrian Federal Chancellery with the question of how data and data-driven approaches could be of help in an unfolding crisis with yet-unknown dynamics.

In a hurriedly convened online meeting, the Hub team decided to take on the challenge: Within hours, we switched to "corona mode." Based on 18 key questions, we formed work packages and assembled special groups to develop a coherent, comprehensive concept to map data-based issues in connection with the COVID-19 crisis. In the following months, the CSH answered questions such as:

—— At what point will the healthcare system become overwhelmed, especially with regard to intensive care beds?

—— How can the (initially very limited) test capacities be substantially increased?

—— How well do individual measures to contain the pandemic work?

—— How important is timing for reducing virus spread?

—— How are testing and tracing optimally used?

—— How can the population, physicians, and patients be informed about the infection situation in their district in a comprehensible and timely way?

—— How can regional lockdowns and travel warnings be put on a quantitative basis?

—— How can supply security be maintained despite lockdowns and supply chain interruptions?

—— How can the mood of the population be measured to determine early on whether and to what extent the population supports governmental measures?

—— How can the economy be optimally rebooted?

—— How can authorities and institutions better prepare themselves for further waves of infection?

Hub researchers became part of several governmental expert teams that are advising the Austrian Prime Minister and the Minister of Health on an ongoing basis. Together with friends and colleagues, the CSH created easy-to-comprehend, easy-to-use tools with corona-related information. Thousands of governmental measures in nations around the world were collected to establish the CCCSL database, which eventually became part of a world-encompassing effort to find the best ways to stop the pandemic.

We showed the impact of lockdowns on movement radii of Austrians. We developed a visualization of the country's imports and exports as a first step towards a better understanding and management of critical supply chains. We published Policy Briefs and studies with, for instance, forecasts when ICU beds in Austria would reach capacity limits (and how to avoid that); how to scale-up corona testing; how to optimally test in nursing homes or how to safely re-open schools, among others.

ALL THE COMPONENTS FOR SUCCESSFUL CRISIS MANAGEMENT

Summing our corona research up, we think we have developed most components for a strategical logistic control of this pandemic: We know the case numbers and have been able to effectively communicate them to the public. We found out which measures work best. We would be able to monitor hospital capacities or pre-existing medical conditions of patients. We see where and how (much) people move and meet. We have devised tailor-made corona strategies for critical institutions like nursing homes or schools. Together with timely, large-scale testing and functioning (!) digital contract tracing (that never materialized), we think we could have beat the virus even before vaccinations were available.

What we have also learned is that in a pandemic, everything is about timing. And good timing only works with the availability of up-to-the-minute data.

In fact, corona made us recognize the great use and need for well-designed, comprehensive databases (and that they often don't even exist). It also became clear that science needs access to this data.

If these two conditions are met—good databases and data access—the CSH really can contribute and even better support a truly evidence-based governance.

CSH COVID -19 Con trol Stra tegies List

The CSH has assembled a huge collection of worldwide governmental measures against coronavirus spread.

Perhaps the most frequently asked question in the first months of the pandemic was which measures actually work—and which ones work better—against the spreading of the disease. Is wearing a mask indispensable, or is its effect negligible? How effective are different distancing rules, temperature checks at airports, or school closings? To find out, one of the first things we did after switching to "corona mode" was to start a collection of governmental measures imposed by countries throughout the world.

Nobody would have thought at the beginning how much work lay ahead of us. While group leaders discussed how to best name, group, and sub-group different kinds of measures, literally the whole Hub team was trawling the Net, digging into publications and studies, checking hundreds of news items and reports in all sorts of languages—including such "exotic" tongues as Russian, Slovakian, Kazakh, Chinese, Hindi, or Icelandic—in order to determine which country implemented what measure on which exact day.

CCCSL IMPRESSED *NATURE* AND THE WHO

In the emergency phase from March to August 2020, over 40 volunteers and researchers were engaged in the project, guided by our tireless Amélie Desvars-Larrive, who eventually took over the project lead.

Several weeks after our efforts began, the World Health Organization (WHO) became aware of the great open-access database and started incorporating it into its "Public health and social measures (PHSMs)" database in April, and *Nature News* featured the CCCSL at length. In August 2020, the constantly updated and harmonized database was published in *Scientific Data*.

PART OF SOMETHING EVEN BIGGER

A year later, in March 2021, the project ceased. However, we are making sure that the precious data—now a compilation of 11,512 government interventions in 57 countries—won't be lost. Amélie is exploring a collaborative approach aiming to integrate the CCCSL into the world's largest intervention database CoronaNet (a project of the Technical University of Munich), which already comprises more than 60,000 measures. The two teams are working on an algorithm that will enable the CSH data to be recoded with the CoronaNet taxonomy. As the algorithm can be used in both ways, this would be a win-win process for all of us.

KNOWLEDGE FOR (FUTURE) PANDEMICS

In February and March 2021, the Hub also served as a co-host of the first COVID-19 PHSMs Data Coverage Conference. The aim of the gathering was to bring corona trackers from all over the world to one virtual table.

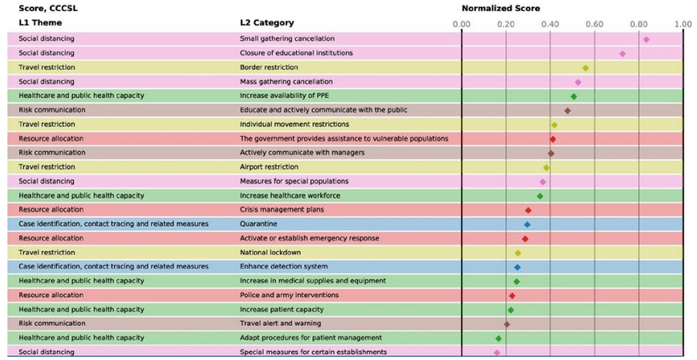
With over 300 registrants and more than 100 representatives of over 50 policy trackers, the meeting was a huge success. In several intensive workshops and discussions on February 10 and 11, the trackers discussed challenges they face, how data collection on health equity measures can be improved, and how public health responses to future pandemics could build upon the lessons learned. Their results and outlooks were shared with international organizations, journalists, and policy-makers in a public online conference on March 3.

The meeting considerably boosted communication, cooperation, and the already great spirit of the (mostly volunteer) tracker community. It further led to the establishment of the COVID-19 Public Health and Social Measures Data Coverage Network, a pioneering platform for discussion, collaboration, and cooperation of corona trackers—world-encompassing science at its best.

A. Desvars-Larrive, et al., **A structured open dataset of government interventions in response to COVID-19**, *Scientific Data* 7 (285) (2020)

Information on the COVID-19 PHSM Network: https://covid19-conference.org/

What Really Works



Our most successful paper. In the first half year after its publication in November 2020, the CSH ranking of the most effective worldwide COVID-19 government interventions was accessed more than 381,000 times.

Which measures work best against the spread of COVID-19? The ranking produced by the Hub became our most successful paper.

After some weeks of collecting governmental interventions, a team of scientists related to the Hub eventually started to disentangle the CCCSL data jumble. Their goal: to quantify the contribution of each measure to reduce the R(t), the famous reproduction number that shows how many people get infected by one sick person on average (to contain the spreading of any disease, the R[t] must be below one).

The final publication in November made use of 6,068 hierarchically coded interventions implemented in 79 territories, including more than twenty US states, European countries, and Asian regions like Japan and Hong Kong. The scientists analyzed the CCCSL data with four different methods—a huge task indeed. On top of that, they validated their findings with two external datasets: the PHSM dataset of the WHO and the CoronaNet project.

SOCIAL DISTANCING, CLOSING SCHOOLS

According to the Hub ranking, the most effective non-pharmaceutical intervention against COVID-19 is social distancing, specifically, the cancellation of small gatherings and the closure of schools and other educational institutions. Next in line are border restrictions and the availability of protection gear such as face masks (remember: most measures were collected in the first wave of the pandemic).

Yet, as principal investigator Peter Klimek has been stressing unceasingly, it is never one individual measure that leads to success. Take the closings of schools as an example: If children cannot go to school, parents of younger children will have to stay at home, too. Inevitably, this reduces potentially contagious contacts of the whole household. "We still don't know exactly to what extent small children are a factor in spreading the virus," Peter said after the publication. "Yet, what we clearly see in our analyses is: If educational institutions are closed, the R(t) goes down by around 0.2."

This relatively small number shows that to combat a pandemic, it will always be necessary to implement a bundle of interventions. Which is good news, Peter thinks: "A hard lockdown certainly is the most effective intervention, but it also has huge negative consequences and should therefore be avoided if possible. What we show is that we can achieve similar results with a clever mix of 'softer' measures." Whereby timing is of utmost importance: The earlier measures are implemented, the more effective they are, Peter and his colleagues found (and have emphasized ever since in hundreds of interviews).

Another well-working intervention is well-designed risk communication, the study found. As the pandemic continues, the threat of negative scenarios is clearly wearing off. In contrast, giving the public insights and reliable information could have long-lasting positive effects in the fight against COVID-19, as well as against future pandemics.

ALTMETRIC TOP 100

The preprint of the paper came out in August and garnered a lot of attention. But the final publication in November went through the roof: The CSH ranking of measures immediately became the most downloaded and discussed paper we have ever published. Altmetric, a company that tracks all aspects of scholarly content in the web, found it to be No. 36 on its Top 100 list of "most discussed science articles of the past year," a list based on 3.4 million works and 87.7 million mentions in 2020. As of May 2021, the paper was accessed more than 381,000 times. We think we can be proud indeed.

N. Haug, L. Geyrhofer, A. Londei, E. Dervic, A. Desvars-Larrive, V. Loreto, B. Pinior, S. Thurner, P. Klimek, **Ranking the effectiveness of worldwide COVID-19 government interventions**, *Nature Human Behaviour* 4 (2020) 1303–1312

Tools, Tools, Tools!

The Hub developed several tools to provide easy—and easily comprehensible—access to a variety of corona-related information.

Relevant information should be easily accessible to the general public. This rule applies even more during times of insecurity and fear. That's why we decided to visualize corona-related information right from the onset of the pandemic.

THE CSH CORONA TRAFFIC LIGHTS

Our most successful interactive tool was the "Corona Traffic Light System" ("Corona-Ampel"), designed and further developed by Wolfgang Knecht and Johannes Sorger. To our knowledge, it was the first tool (at least in German-speaking countries) that used a traffic light scheme to visualize infection numbers and to gauge the situation in a region. Especially in the first months when the colors were constantly changing, the tool was used by (tens of) thousands of people every day.

The first version featured a map of Austria showing newly confirmed cases for each political district. With a slider, users could move back in time and see where, and when, colors, and thus infection rates, changed. By clicking on a district, absolute and relative case numbers were depicted.

Over time, the tool was considerably extended and refined: First, the vis team added a worldwide map. Europe was eventually broken down into districts. A second color scheme was added, enabling users to switch between the typical traffic light of colors red, yellow, and green (supplemented by a color-blind compatibility mode) and the more detailed, six-color European Centre for Disease Prevention and Control (ECDC) scheme. A "Trend" map further indicates whether infection rates in a region or country are constant, rising or falling. The most recent extension is an immunization tracker.

https://vis.csh.ac.at/corona-traffic-light/world

CSH HEALTH CARE INFO POINT

Early in the pandemic, CSH's Peter Klimek and his team developed a tool that supplies Austrian doctors with detailed, COVID-related information. The idea was to have all relevant, up-to-date information in one place to better prepare practitioners for a possible run on their practices.

The "CSH Health Care Info Point" provides information to doctors about the number of confirmed coronavirus cases and growth rates in their district. It also displays the number of doctors in different medical fields, as well as the size of various risk groups per district.

The CSH had plans to extend the service, for instance, with a patient behavior monitor. "When corona infections were on the rise, many people in need of a doctor were afraid to leave the house and seek necessary medical help," Peter explained at that time. "If health authorities had a tool that showed them a sudden regional decline in consultation rates, they could take countermeasures to avoid undertreatment." However, as we did not get access to the necessary data, we had to skip these (and several other) plans.

https://csh.ac.at/covid19/healthcare

AUSTRIA SOCIAL MEDIA EMOTIONS DASHBOARD

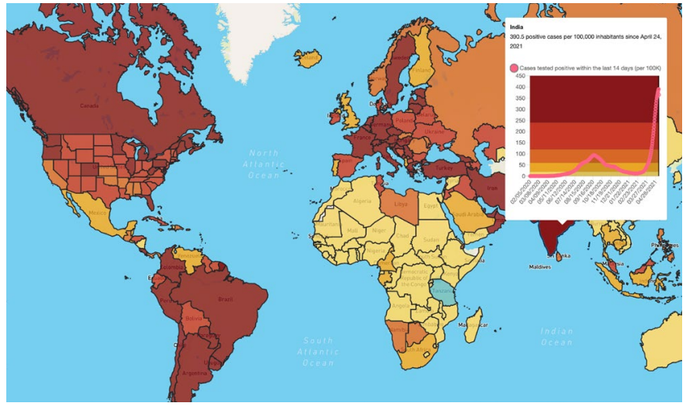
For politics, but also for psychosocial services, it is of great importance in times of crisis to know about changes in people's moods and well-being. Which feelings are evoked by the extreme situation? Are people desperate and anxious, or are they dealing with it calmly and positively? Do they support the governmental measures, and at which points do mood changes become apparent?

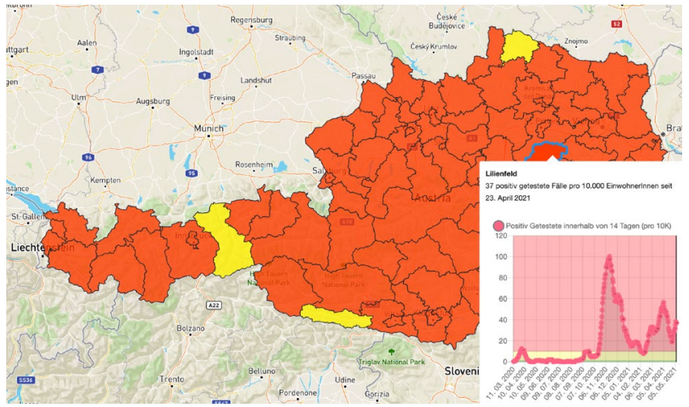
To track the mood in the Austrian population, David Garcia and his team developed a live tracker of emotions expressed on several Austrian online platforms. Their "Austria Social Media Emotions Dashboard" continuously records expressions assigned to different emotions on three platforms: the online forum of the daily newspaper *Der Standard*, on Twitter, and on a platform mainly used by young people between 18 and 28. The Dashboard shows increases of expressions of anger, fear and worry, sadness, and positive emotions. In addition, it records words that express a prosocial attitude (empathy, helpfulness, support, etc.), as well as terms that describe social interactions and relationships in the broadest sense (friends, parents, brother, entertainment, educator, care, etc.).

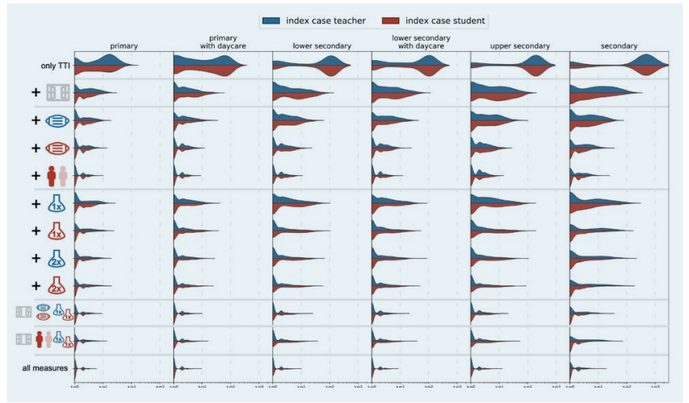
https://mpellert.at/covid19_monitor_austria/

HOW CAN SCHOOLS BE SAFELY RE-OPENED?

In a simulation (published as a Policy Brief in January 2021), Jana Lasser and other CSH scientists identified measures that effectively control the spread of SARS-CoV-2 in schools. The scientists used Austrian data on 616 clusters involving 2,822 pupil cases and 676 teacher cases to quantify the impact of interventions such as room ventilation, class size reduction, mask wearing during lessons, and school entry testing.







They found that different school types require different combinations of measures to achieve infection control. In primary schools, for instance, at least two measures need to be implemented. In secondary schools, where contact networks of pupils and teachers become increasingly large and dense, a combination of three measures is necessary. The scientists suggest that school type-specific combinations of measures would allow for a controlled opening of schools.

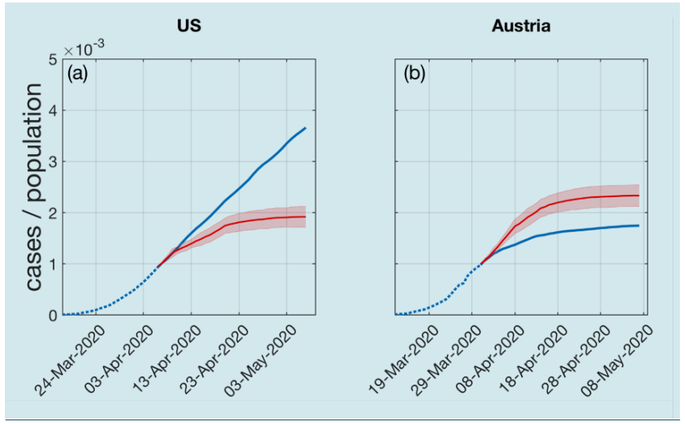
Based on these data and simulations, CSH vis expert Johannes Sorger developed an interactive school simulation: the "COVID-19 Prevention Measure Explorer for Schools." It allows users to configure various school types (primary school with or without daycare, secondary school, etc.) and sizes, such as the number of floors and classrooms, of pupils per class, or of teachers. In a next step, safety measures against virus spread can be chosen, such as different testing strategies, class size reduction, mask wearing of teachers and/or pupils, or window opening frequency, and the "index case" has to be defined (i.e., the person who brings the virus to the school: teacher or pupil).

The simulation now shows where and how fast infections will proliferate in that specific school setting.

https://vis.csh.ac.at/covid-schools/

L. Richter, D. Schmid, J. Sorger, S. Thurner, P. Klimek, **Effektivität von Präventionsmaßnahmen für SARS-CoV2 und seine transmissibleren Varianten für eine nachhaltige Öffnung der Schulen**, *CSH Policy Brief* 1/2021

Explaining Atypical Curves



Contact networks. If the US had introduced measures to reduce the average degree in contact networks from five to 2.5 people early on, this could have almost halved the number of COVID-19 infections until the first week of May 2020. If Austria had implemented its strict measures against coronavirus spread ten days later, the delay would have resulted in up to 30 percent more cases, according to the Hub model.

Most infection curves in the COVID-19 pandemic don't show the expected S-shape, but a linear growth after the first peak. Hub scientists found out why.

After the first COVID-19 peak, countries explained the decrease of infection numbers mainly through non-pharmaceutical interventions. Yet some explanations fell short: The linear rise of infection curves many countries displayed after the first peak was not the S-shaped curve expected from standard epidemiological models—in fact, the observation is practically impossible to understand with traditional epidemiological models. This inspired Stefan Thurner, Peter Klimek, and Rudolf Hanel to look for further explanations. For the standard modelling procedure, they used a so-called compartmental model with SIR models, extended by cluster transmission.

INFECTION CURVE FORM BETTER EXPLAINED BY NETWORKS

The three Hub scientists show that by taking some relevant network features into account, the observed linear growth can be naturally explained. The SARS-CoV-2 virus, they found, spreads in small, limited clusters rather than through superspreading events. "Most people go to work, get infected and spread it to two or three people at home, and then those people go to work or school again. The infection is thus basically jumping from cluster to cluster," says Stefan.

The team shows that there is a critical number of contacts—they call it degree of contact networks or D_c — below which linear growth and low infection prevalence must occur. They found Dc to equal 7.2.

Assuming that people circulate in a coronavirus-relevant network of about five people, and even less during an effective lockdown, the curves will stay linear, and the virus cannot spread uncontrollably. Yet, if those people start partying again, the curves can quickly turn back into exponential growth. "The network density influences the transmission rates," says Peter. "We show the importance of reducing the network density below this specific critical point."

LINEAR CURVES IN THE US AND AUSTRIA

To check their model, the scientists compared Austria, a country which responded with a severe lockdown early on, with the United States, which initially did not impose severe measures. The model worked for both scenarios: linear curves in both countries; in the case of the US (and other countries like Sweden) they just happened on a much higher level.

"The model not only allows us to understand the emergence of the linear growth regime, but also explains why the epidemic comes to a halt far below the levels of herd immunity," the scientists write in their paper. "Further, it allows us to explain the fact that in countries which are beyond the (first) maximum of the epidemic, a relatively small number of daily cases persist for a long time."

The results raise serious concerns regarding the applicability of standard compartmental SIR-like models. "Network effects must be taken into account to understand postintervention epidemic dynamics," Stefan, Peter, and Rudi conclude.

S. Thurner, P. Klimek, R. Hanel, **A network-based explanation of why most COVID-19 infection curves are linear**, *PNAS* 117 (37) (2020) 22684–22689

Supporting Decicion Making

CSH Policy Briefs communicate political relevant scientific insights and support decision-makers.

In early 2020, the Hub started to publish Policy Briefs and studies (most of them in German as they mainly refer to the situation in Austria), providing estimations, models, simulations, or assessments of the current situation, as well as recommendations for action. Several of these publications became crucial contributions to corona-related discussions in Austria and have received much attention from politics and the media.

BOOSTING SAMPLE POOLING

In March 2020, when corona testing capacities were still very limited, Rudolf Hanel and Stefan Thurner presented a method to boost test efficiency by a factor of 10: They proposed to pool the samples and provide a formula for an optimal pool size depending on the infection rates in the population.

"CALL 1450"—SUCCESSFUL PREVENTIVE STRATEGY IN VIENNA

In May 2020, a Hub team was able to show the efficiency of an early isolation strategy first implemented in Vienna: People with symptoms were advised not to leave home to see a doctor or visit a hospital, but rather to call 1450 (the Health Advice Hotline) and wait for a doctor to come and test them at home.

By using a new epidemiological model of the German Robert Koch Institute, the scientists showed that this early isolation helped to considerably curb infection numbers. According to their study, case numbers in Vienna would have been almost three times higher without the service than they actually were, and many hospital cases and deaths were avoided.

EARLY LOCKDOWN IN AUSTRIA HIGHLY EFFECTIVE

The same team simulated the effects of the early lockdown in Austria, which was imposed in mid-March, and compared it to possible case numbers (a) without a lockdown, (b) with a lockdown one week or, respectively, (c) two weeks later.

The simulation showed the efficiency of lockdowns: Without any measures, case numbers and deaths would have been four times higher at the beginning of May, the capacity limits of the healthcare system would very likely have been surpassed. A one-week delay in shutting down the country would have doubled the cases; a lockdown start in April (a two-week delay) would have tripled them.

OPTIMIZED PREVENTION OF VIRUS SPREAD IN NURSING HOMES

A team including CSH scientists Jana Lasser, Johannes Sorger, and Peter Klimek developed a novel agent-based epidemiological model for the spread of SARS-CoV-2 in nursing homes to identify optimal preventive testing strategies for Caritas, the largest nursing home operator in Austria.

Their results have not been published yet, but were summarized in a preprint: They found that the effectiveness of preventive screenings critically depends on the timespan between the test and the test result, the detection threshold of the viral load for the test to give a positive result, and the screening frequencies of residents and employees. The resulting testing strategy was implemented in Caritas nursing homes and proved to be highly efficient.

J. Lasser, J. Zuber, J. Sorger, E. Klager, M. Kletečka-Pulker, H. Willschke, K. Stangl, S. Stadtmann, C. Haslinger, P. Klimek, T. Wochele-Thoma, **Agent-based simulations for optimized prevention of the spread of SARS-CoV-2 in nursing homes** (submitted Nov 16, 2020)

Details of these and all other CSH Policy Briefs can be found on pp. 82f or on the CSH webpage (https://www.csh.ac.at/csh-policy-briefs-research-briefs/).

SELECTED RESEARCH FINDINGS

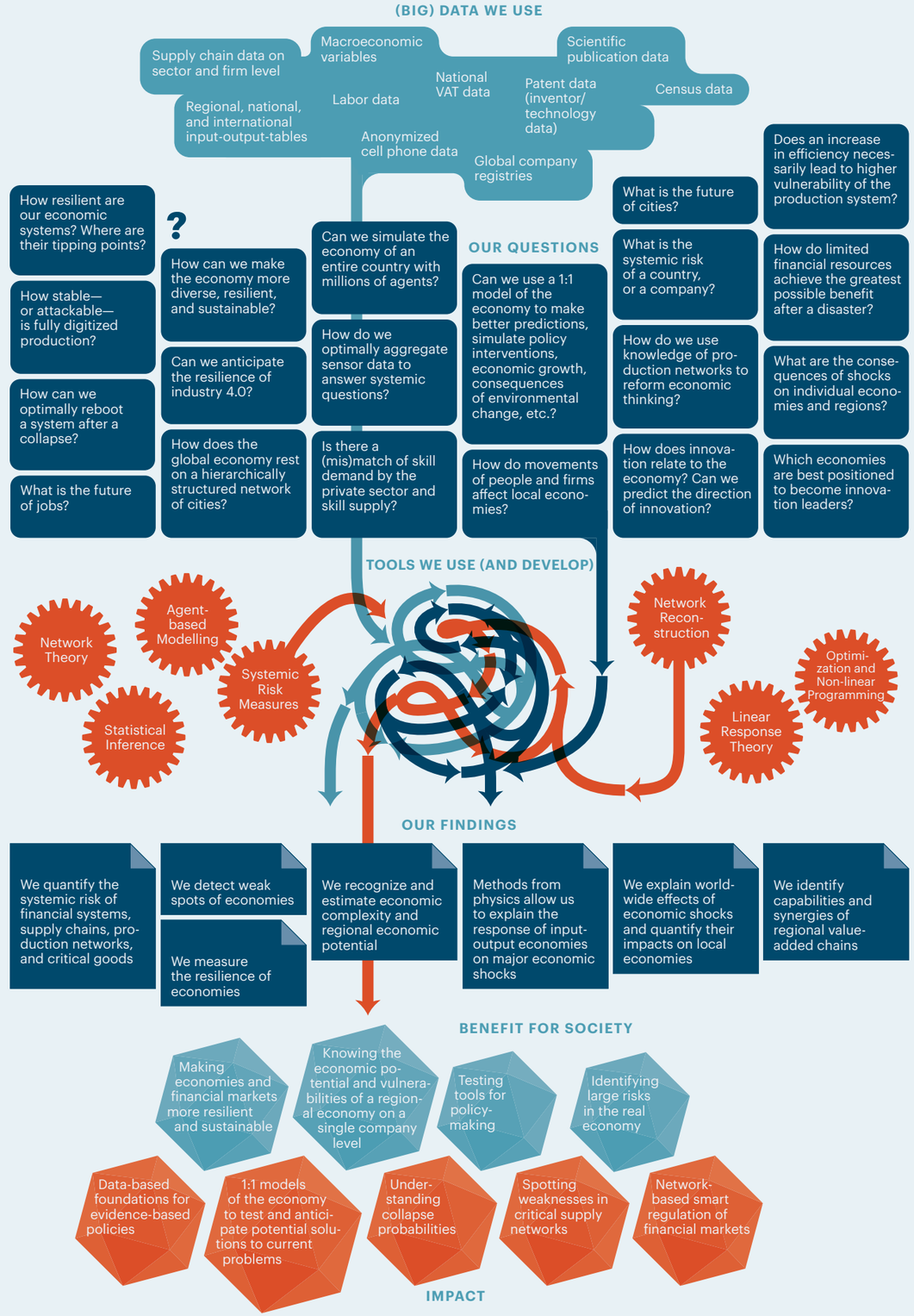
Network Economics

The economy is a collection of tightly interconnected dynamical networks linking people, funds, products, and ideas.

There is no such thing as "the economy." What we (should) call the economy is a highly complex system involving biology and ecosystems, production, human and group behavior, technology and education, finance, healthcare, culture, innovation, creativity, fairness, inclusion, distribution, sharing, or trade, and much more. All these aspects are mutually dependent, entangled in networks, and networks of networks, which constantly evolve, adapt, and change.

Conventional economics falls short in dealing with such dynamic complexity. When we want to understand socio-economic processes, we need a new, a broader—well, simply a complex—approach. This is what we pursue and develop at the Hub on multiple scales.

One example is the concept of a data-based 1:1 model of the Austrian economy our researchers are building. Such a model will allow us to better understand resilience, collapse probabilities, efficiency, fairness, and unintended consequences of policy interventions. We simulate scenarios that indicate possible solutions for current problems before they occur. We try out policy interventions to find unintended consequences long before they are actually implemented in reality. The model can be virtually shocked to see how stable and resilient the economy is, to identify where its weak points are, and how these could be improved.



Shocking Economics!

CSH researchers borrow a method from physics that allows the prediction of how economies worldwide respond to major disturbances.

In classical physics, Linear Response Theory (LRT) explains, e.g., how electric or magnetic substances react to strong electrical or magnetic fields. Hub researchers showed that it applies just as well to input-output economics. “Modern macroeconomics are still based on the assumption of equilibria,” says Peter Klimek, one of the authors. “But a shock knocks economies out of a state of equilibrium.” While macroeconomics fails in times of crises, such as the 2008 Great Recession or ex-president Donald Trump’s tariffs on EU steel and aluminum in early 2020, the novel method borrowed from physics makes the effects of major events on out-of-equilibrium economies computable for the first time. The US think tank Aspen Institute called the findings one of the Five Best Ideas of the Day on April 16, 2019.

The new theory complements current economic models in several ways.

FIRST: CALCULATING RESILIENCE

“We can determine the resilience of an economy,” explains one of the authors, Peter Klimek. Each country has different industries and depends on various imports and exports. These interdependencies can be seen in easily available datasets. The scientists can calculate how susceptible a country and its different production sectors are to disturbances. They used ex-US president Donald Trump’s tariffs on EU steel and aluminum as an example.

SECOND: MODELLING OUTPUTS

Furthermore, they can quantify how much a shock in one corner of the world affects the production of a given sector far across the globe. Modelling responses to shocks helps answer questions like why it took economies so long to recover from the 2008 recession. “A shock does not evaporate,” Peter points out. Just like a rock that is thrown into a still pond, shocks produce ripples that will run through the whole system, following each of its interdependent connections. The scientists found that it typically takes six to ten years before all sectors of an economy have fully digested a shock.

THIRD: TESTABLE PREDICTIONS

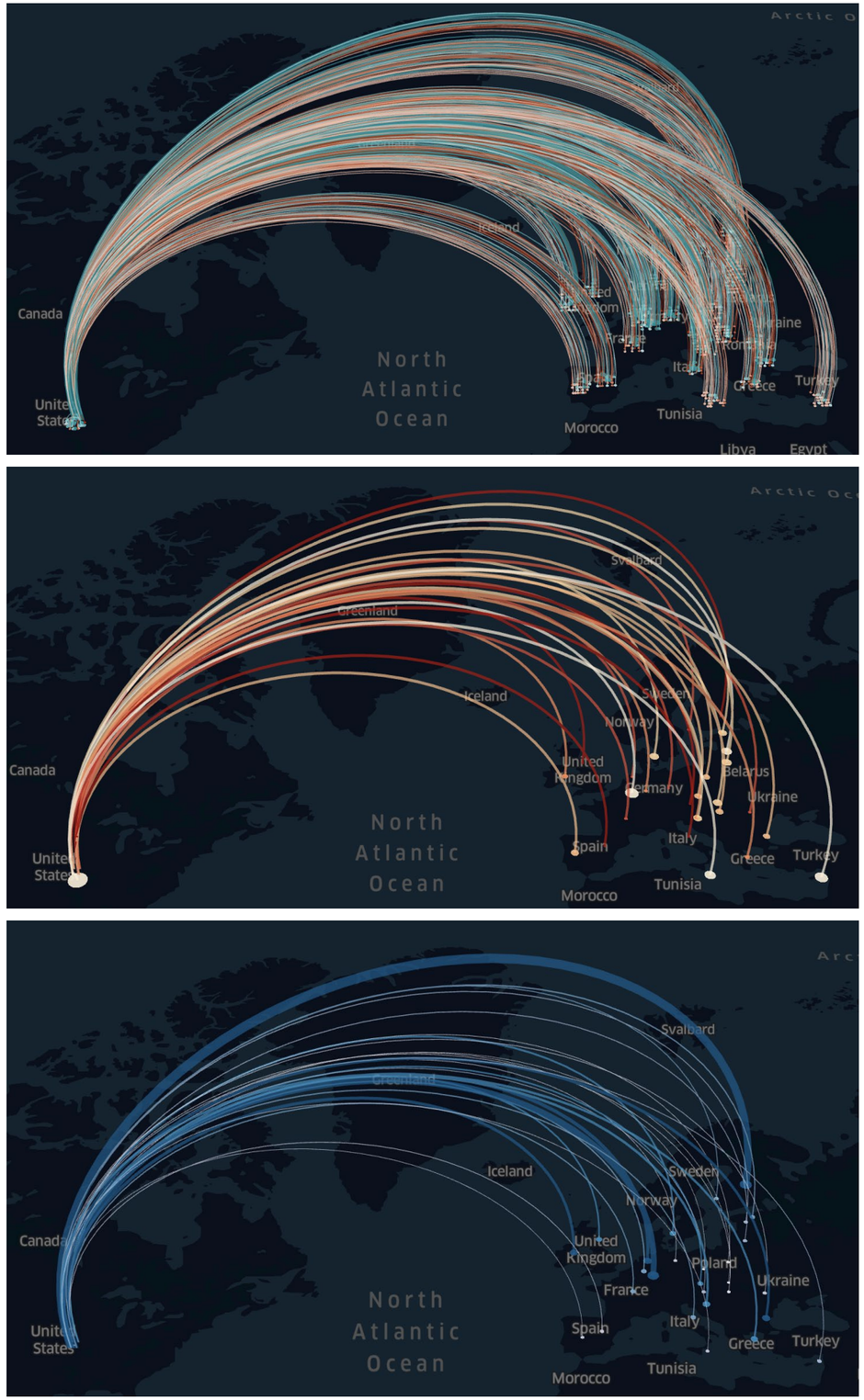
Using the input-output data of 56 industrial sectors in 43 OECD countries from the years 2000 to 2014, the scientists then tested the accuracy of different economic projections that were dealing with the aftermaths of 2008. Their method outperformed all standard econometric forecasting methods—most of them substantially. The vision is to eventually be able to calculate global effects of all kinds of shock scenarios that can happen anywhere.

P. Klimek, S. Poledna, S. Thurner, **Quantifying economic resilience from input–output susceptibility to improve predictions of economic growth and recovery**, *Nature Communications* 10 (1677) (2019) 1–9

(Figure on the right) Effects of steel and aluminum tariffs by the Trump administration on the EU28. Each arc shows the impact of Trump tariffs on one economic sector in Europe. The blue lines show countries and sectors that gain output from the shock, red lines indicate a decreased output. The darker the lines, the bigger the effects are.

(Middle) The electricity sector shows a decrease in output consistently through all countries due to less energy being required in the EU steel and aluminum manufacturing sector.

(Bottom) The manufacturers of automotive vehicles profit from the tariffs. The reduced demand of EU steel and aluminum in the US increases the supply of these metals in Europe. This leads to positive effects for sectors like the automotive industry that require the input of these metals.



Supply Chain Check

Gaining a better understanding of the supplier networks of a national economy helps to identify weak points and allows the economy to become more resilient and crisis-resistant. In a Policy Brief, Hub researchers determined the supply chain risks in the Austrian economy for the first time. This shows the direct applicability of our basic research.

The risk of a crisis of supply chains has increased continuously over the last decades due to globalization, especially the outsourcing of production. Just how big this risk is became visible through the COVID-19 pandemic: There were crises in meat supply, car production, medical goods... In Austria, a brief shortfall in yeast deliveries made clear how quickly production downtimes can occur.

If a company is no longer supplied with essential production components and once its own stocks are used up, it cannot produce; in the trade or service sector, production comes to a standstill. If preliminary products cannot be delivered to other companies, delivery failures can spread through the entire supply chain network in cascades and, in the worst case, lead to the complete failure of entire branches of industry—a so-called supply chain collapse.

In a Policy Brief published in June 2020, CSH researchers investigated what supply chains in Austria look like, how resilient the companies' supplier networks are, or how long they can continue to produce after a failure of their main suppliers.

DEPENDENT ON SINGLE AND FOREIGN SUPPLIERS

The investigation showed a high dependence on individual suppliers. More than one-third of the companies—small and large firms alike—had at least one supplier whose failure would lead to a complete shutdown of their operations. The situation was similar for all sectors, i.e., trade, construction, services, and manufacturing. About 40 percent of all suppliers came from abroad. Furthermore, the companies had no alternative for 40 percent of their suppliers.

"The Austrian supply chain as a whole is only robust to a limited extent," wrote Tobias Reisch, Christian Diem, William Burton, and Stefan Thurner. "The high proportion of suppliers for whom there are no currently available alternatives increases this risk. Therefore, systemically-relevant cascade-like supply crises could occur relatively easily."

The scientists emphasize the great dependence on foreign suppliers. "Stocks in Austria are relatively high and can buffer a collapse in the event of supplier failures. On average, production can continue for about one month." Yet, while Austrian companies could resume normal operations relatively quickly (within two weeks), the authors point out that a precise analysis and knowledge of supplier networks, especially among manufacturers of critical goods, is missing. If they were available, weaknesses could be identified, and the resilience of the Austrian economy as a whole could be increased.

The Hub team suggests following the example of other countries and establishing an interdisciplinary working group that includes representatives from science, the public sector, and industry to identify and collect the necessary facts and figures for supply chain analyses and risk assessment.

T. Reisch, C. Diem, W. Burton, S. Thurner, **Wie robust sind die österreichischen Lieferketten?** *CSH Policy Brief* 6/2020 (June 16, 2020)

Economics Need to Consider Networks

Ever since its beginning as a scientific field 300 years ago, classical economics has consistently ignored the role of networks. Complexity science offers a radically new approach, based on the ability to understand the dynamics of networks.

The limits of what can be done with classical economics models with aggregated variables has become apparent in the obviously limited predictive power even for gigantic systemic events such as the two recent financial crises. We think the reason is that it ignored a most important property: That the dynamics of the economy, its efficiency, resilience, and its ability to change and adapt are due to and guided by the detailed structure of networks and their changes.

Practically all aspects of the economy are dominated, shaped, and determined by networks, from the invention of goods and services to their first realization in prototypes, the financing and funding for their development and production, to the production itself, the distribution, marketing and sales, up to usage and eventually recycling.

Taking a closer look, we see that the various networks that build and constitute the economy themselves are nodes in a network. Structurally, the economy is a network of networks. The levels of interconnectedness becomes apparent by, for example, looking at the intricate linking of financial networks or production chains.

Network structures determine flows of finances, materials, funding, talent, goods, etc. These network structures limit and constrain the room for decisions by individuals, firms, banks, and political decision-makers in general. Adaptations over time do not happen by chance but follow detectable patterns and rules that can be learned from data. An understanding of these processes—and of networks—offers a handle for understanding economic dynamics in a dramatically improved way.

Yet, the dynamics in ever-evolving systems is far from being understood, even less so the dynamics of networks of networks. To base the understanding of the economy on the dynamics of its underlying networks is an entirely new approach—one of the fundamental aims of the relatively new science of complex systems.

A NEW TYPE OF MODELLING

It is generally hard and practically impossible to understand the dynamics of how networks shape and determine complex systems and how they lead to the emergence of efficiency, robustness, and resilience without new mathematical tools and concepts. The past two decades have seen a boost in mathematical and statistical developments to describe, handle, and eventually manage networks, and consequently (some) complex systems, too.

A game-changer is the availability of massive datasets that represent various economic networks at a high temporal resolution. We now can rebuild and model economies in computer simulations, so-called data-driven agent-based models that represent a new generation of modelling. (Agent-based models that are not driven on large datasets have been proven to be of very limited practical use!)

Economic networks that have become available in recent years include financial networks, supply chains, and labor flows, just to mention a few—all at a granular scale of companies, and even individuals. For example, these empirical networks have led to recent breakthroughs in the conceptualization and quantification of systemic risk in financial markets.

These developments open entirely novel ways of systemic risk management that are fundamentally different to classical approaches (like the current Basel-type banking regulation that—to a large extent—ignores financial networks).

If big datasets of granular economic data are merged and combined in a coherent way that allows for a realistic representation of the relevant agents and their interactions in an economy, it becomes possible for the first time to reproduce and fundamentally understand the origin of efficiency and resilience in an economy. With the quantification of network-based efficiency, systemic risk, and resilience, one begins to systematically identify structural weaknesses in economies, bottlenecks for growth, and structural reasons for inefficiency.

A NEW PARADIGM

Within this new paradigm, it becomes possible to capture a range of scenarios in a quantitative fashion. For example, the effect of taxes or regulations can be analyzed in terms of wealth distribution in specific contexts. It allows us to identify constraints on the growth of companies or the systemic relevance of certain producers in regional markets. Moreover, it enables us to detect the unintended consequences of changes in economic networks due to new regulations, such as carbon taxation.

A hot topic is to use data-driven agent-based models to anticipate potential social costs (e.g., in terms of jobless rates) in relation to newly forming opportunities on newly emerging economic networks of the green transition. In short, a data-driven network-based approach to economics eventually allows for better predictions.

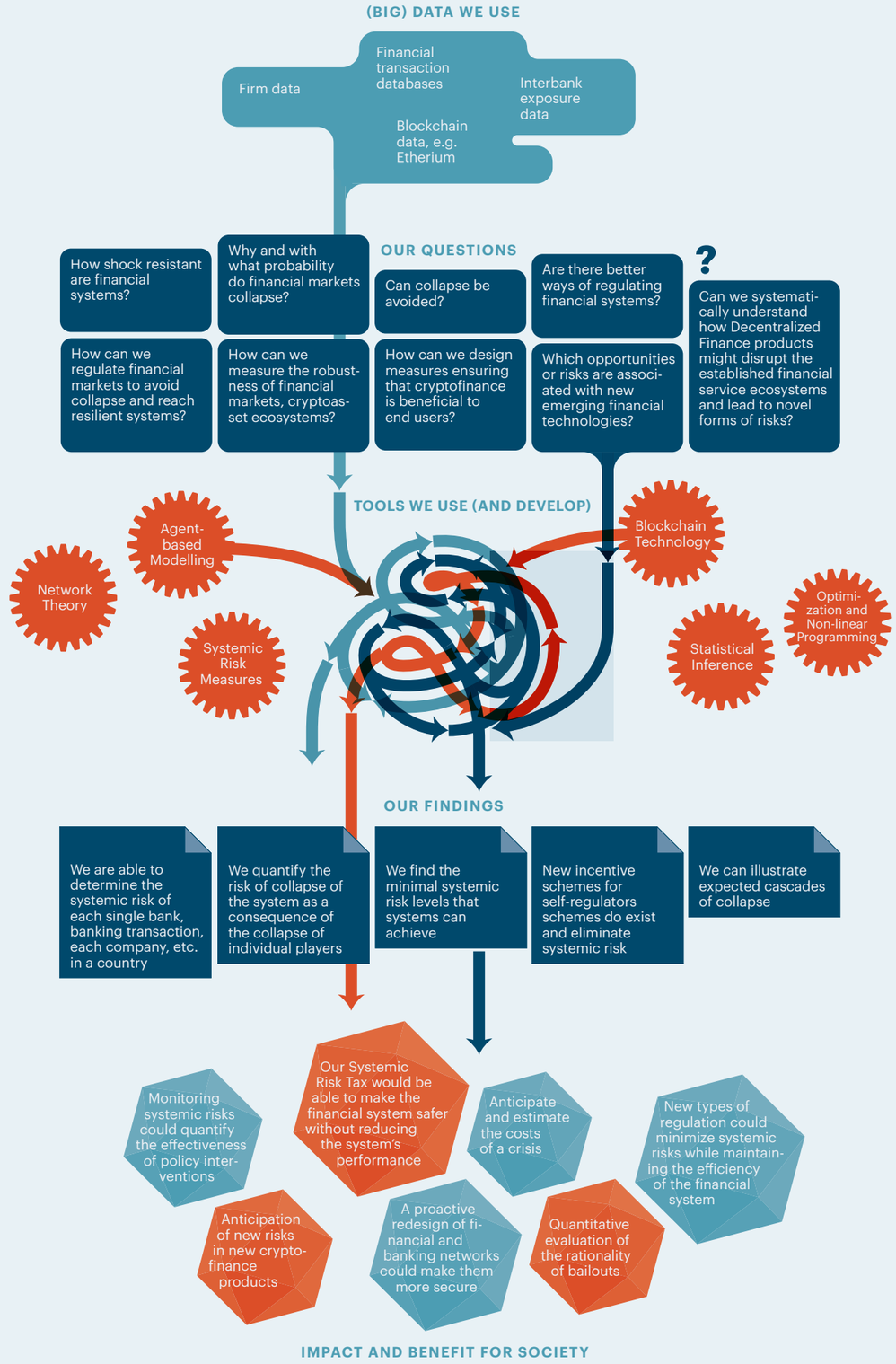
SELECTED RESEARCH FINDINGS

Financial Markets & Crypto finance

Banking and financial market crises cause enormous costs for the public. Until recently, it was almost impossible to predict which banks or transactions are associated with a high systemic risk, i.e., which would affect entire banking networks in the event of a failure. Thanks to the electronic registration of every single financial transaction, together with newly developed methods, the CSH can determine the systemic risk of each bank or interbank transaction.

Estimating the systemic risk of single parts of a system allows us to quantify the risk of collapse of individual players as well as the entire system, and the associated consequences. Subsequently we can compute how a redesign of the underlying financial networks would lead to a much more secure financial system, while maintaining its current level of performance. With this special expertise, the Hub can contribute to the establishment of a new generation of financial regulation: regulations that minimize the systemic risk while maintaining the efficiency of the financial system.

Another field of expertise that is currently being built up at the Hub together with the AIT—one of our founding members—is the area of systemic risks in cryptofinance. Our scientists focus on the analysis of Decentralized Finance (DeFi) protocols and services.



70% Less Damage in Case of Collapse

With a simple method, Hub scientists were able to cut the potential damage caused by collapsing banks by up to 70 percent without negative impacts on the system. The findings underline the importance of considering network effects in the financial sector.

How should the high systemic risk in financial systems be dealt with? The Hub has the answer: Re-arrange their networks!

After major banking crises, like the big crash in 2008, the world always calls for better regulations. Traditionally, the focus was on increasing the equity capital of banks. CSH researchers question this stand-alone approach, as it neglects the network structure of the system.

Christian Diem, Anton Pichler, and Stefan Thurner investigated how much the damage of a systemic crash can be reduced solely by re-arranging the mutual connections between institutions. Their method shows "a surprisingly high optimization potential of up to 70 percent," says Christian, a PhD candidate at the Hub and first author of the study.

RE-ARRANGING BANK CONNECTIONS

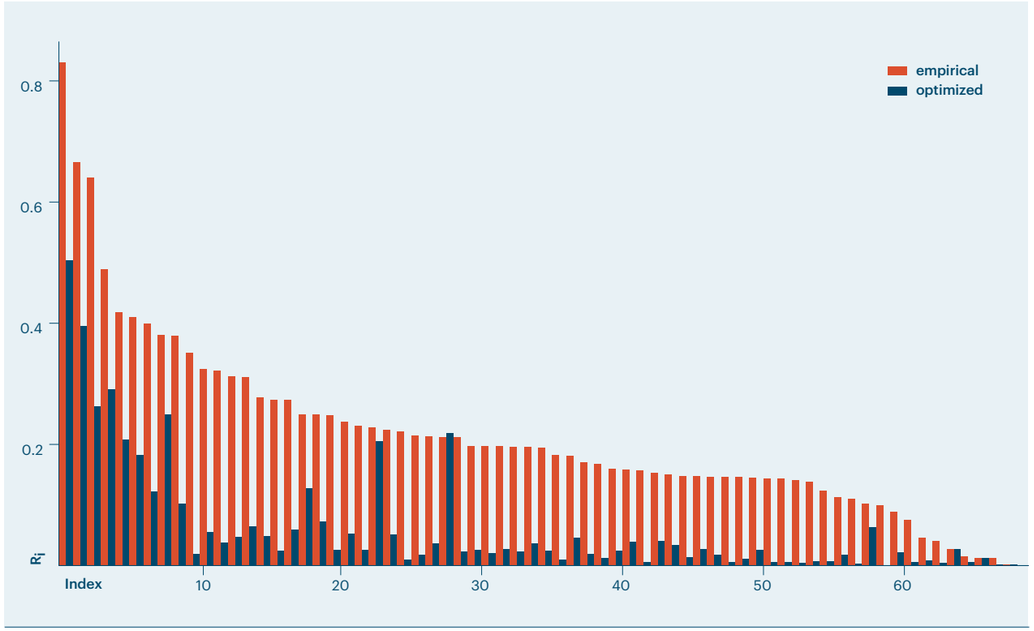
"Banks don't stand alone," Christian explains. "They are linked to, and strongly dependent on, each other by financial contracts, for instance, by credits." Links create networks—in this case the interbanking network.

Complexity science has proven that the systemic risk of any single bank as well as of the entire financial network depends on the distribution of links. "We developed optimization algorithms to reallocate banking loans," Anton, one of our Junior Fellows, points out. "To avoid possible negative effects caused by this process, we added special conditions to the algorithms," he says.

On the one hand, the scientists wanted to assure that the individual risk of a bank does not increase; on the other hand, that the total amount of loans in the network does not decline.

To test their approach, the scientists ran their algorithms on an anonymized dataset of the 70 largest Austrian banks. Together, these banks covered 71 percent of the country's interbank market volume in the years 2008 to 2010.

They found that the systemic risk was especially high when large banks were closely linked. Yet, by re-allocating the lending partners, an entirely new network emerged: with a far lower risk for systemic failure, while the amount of money lent and borrowed in the network remained the same.



Network optimization reduces systemic risk. The restructuring of financial contract networks has huge potential for reducing domino effects between financial institutions. The figure shows the systemic risk index for the 70 largest banks in Austria (in red), i.e., the estimated size of the domino effect it triggers upon its default. Blue is the systemic risk index of these banks obtained by our network optimization. The method works particularly well for smaller banks: They become unrisky. Note that in the optimized network, each bank still borrows and lends the same amount of money to other banks—it only changes the lending partners.

SYSTEMIC RISK REDUCTION

The term "systemic risk" describes the hypothetical effect of individual bank failures on the entire banking system. An example is the bankruptcy of Lehman Brothers in 2008. "Links allow a domino effect: The collapsing institution affects the other banks it is connected to; these banks, again, affect their neighboring banks, and so on," Anton explains. In a network with high systemic risk, the failure of a single knot has the potential to crush the whole system. This can be avoided by the redistribution of links. "High equity ratios in banks may make the falling of a single domino piece less likely. But if a bank collapses nonetheless, our method helps the other pieces not to fall either," adds Christian.

NEW WAYS OF REGULATIONS

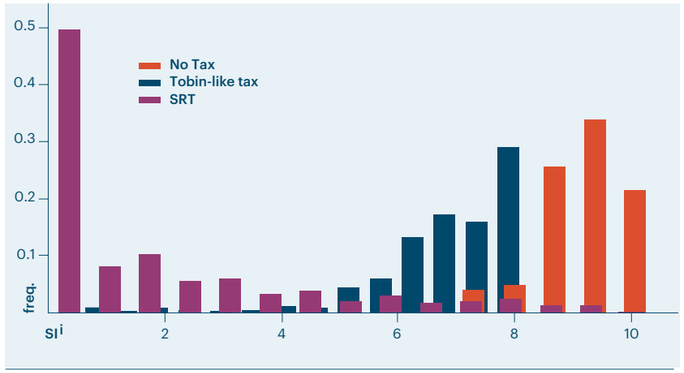
The findings have far-reaching implications for regulators and supervisory bodies such as the European Banking Authority EBA or the European Central Bank ECB.

"To reduce the risk of collapse, regulators must start with the networks," emphasizes Stefan. Future regulatory measures should include a focus on the connections between banks rather than on bank equity alone. "To achieve a comparable risk reduction of 70 percent by increasing bank equity, you would have to raise equity levels by another 230 percent on average. This would be a huge burden on banks," he says.

Instead, the new approach could be of use for monitoring existing regulations: Do they actually reduce the systemic risk and make the network safer? Regulators could even create a new kind of incentive to influence decision-making processes in the banks, the scientists claim. "We could design these incentives in a way that automatically leads to safer networks," maintains Stefan, referring to the Systemic Risk Tax (SRT) as an example.

C. Diem, A. Pichler, S. Thurner, **What is the minimal systemic risk in financial exposure networks?** *Journal of Economic Dynamics and Control* 116 (2020) 103900

Taxing Systemic Risk



A tax to make the banking system safer. Difference in the systemic risk of a bank (= total value of losses in a bankruptcy cascade caused by the failure of that bank): red without tax, blue with Tobin-like tax, green with Systemic Risk Tax (SRT).

What if there were a truly fair transaction tax? A tax only levied on high-risk behavior while not burdening the economic performance of the whole system? Hub researchers had a sparking idea.

The scientists developed a tax, and called it the Systemic Risk Tax, that makes the banking system more resilient and disappears by itself once the network becomes risk-free.

In the past it was not possible to determine the systemic risk of networks: Too many variables were to be taken into account for the calculating capacity of humans or even earlier computers. "However, with supercomputers and a few new, clever mathematical ideas, we can obtain such information from Big Data," CSH President Stefan Thurner points out. For instance, he and his team were able to determine the systemic risk of each bank in a country; yes, even of each single transaction between those banks for the first time.

Based on that, Stefan developed a totally new taxing concept together with his former student Sebastian Poledna: Systemic risk taxing "punishes" only those transactions that pose a systemic risk to the system as a whole. The scientists add the tax as a surcharge on systemically risky financial transactions. The higher the systemic risk, the higher the tax will be.

SRT LETS THE SYSTEMIC RISK DISAPPEAR

Transactions with low or no systemic risk will be cheaper than risky options. As a consequence, banks will choose those lower taxed, and thus the less risky, transactions. As the scientists were able to show in several papers, this behavior automatically changes the banking system: Its systemic risks will first redistribute, diminish, and eventually disappear.

A banking network re-shaped in that way is much less vulnerable to crises like the collapse in 2008, the team claims. "The new tax will automatically lead to a much more resilient system—in sharp contrast to the Basel III banking regulation by the way, which was set up to reduce the risk but has failed to do so," says Stefan.

Another advantage of the Systemic Risk Tax: Its implementation would not reduce the economic performance and efficiency of the financial system of countries or the overall quantity of inter-banking transactions. Again, this is in contrast to another (quite famous) transaction tax—the "Tobin" tax—or the Basel III regulation.

M. Leduc, S. Thurner, **Incentivizing resilience in financial networks**, *Journal of Economic Dynamics and Control* 82 (2017) 44–66

S. Poledna, S. Thurner, **Elimination of systemic risk in financial networks by means of a systemic risk transaction tax**, *Quantitative Finance* Volume 16 (10) (2016) 1599–1613

S. Poledna, O. Bochmann, S. Thurner, **Basel III capital surcharges for G-SIBs are far less effective in managing systemic risk in comparison to network-based, systemic risk-dependent financial transaction taxes**, *Journal of Economic Dynamics and Control* 77 (2017) 230–246

Cryptofinance: A New Research Field at the Hub

In late 2020, the Hub entered new ground: cryptofinance! No, we did not get rich with Bitcoin speculations. We rather intend to find ways of making cryptocurrencies and related products safer.

Lacking a full understanding of financial products and their associated risks can have serious systemic consequences, as financial crises in the past have impressively shown. While traditional finance is now largely regulated, Decentralized Finance (DeFi) stands for a new financial paradigm that aims at disrupting established financial services ecosystems.

DeFi offers financial services and products as blockchain-based smart contracts. This provides the possibility of creating complex financial products and embedding them in new governance models, which, however, involves risks that have not yet been fully understood and could have unforeseeable systemic effects. Examples include decentralized cryptoasset exchanges such as Uniswap or distributed lending protocols such as Maker or Compound.

The development of DeFi protocols is still in its infancy, but their market capitalization has grown rapidly from just under 4 billion to 11 billion USD within three months in fall 2020 alone. Therefore, it is time to think about how such protocols actually work and what opportunities and risks are associated with them.

THE CSH AND AIT ARE JOINING FORCES

The AIT and the CSH have recently joined forces, aiming to build an interdisciplinary team of scientists focusing on the analysis of Decentralized Finance (DeFi) protocols and services. The AIT has many years of experience in the analysis of cryptoasset ecosystems—a community of actors who interact as a system and are linked together through cryptoasset transfers, such as Bitcoin or Ethereum, which operate on Distributed Ledger technology—, and a suitable tool to do this, its GraphSense Platform. The CSH, on the other hand, has a strong background in analyzing network structures of financial markets and quantifying their associated risks.

We expect novel scientific methods from this cooperation that allow assessments of technical and socio-economic risks associated with DeFi protocols, as well as analyses of specific protocols and services.

SELECTED RESEARCH FINDINGS

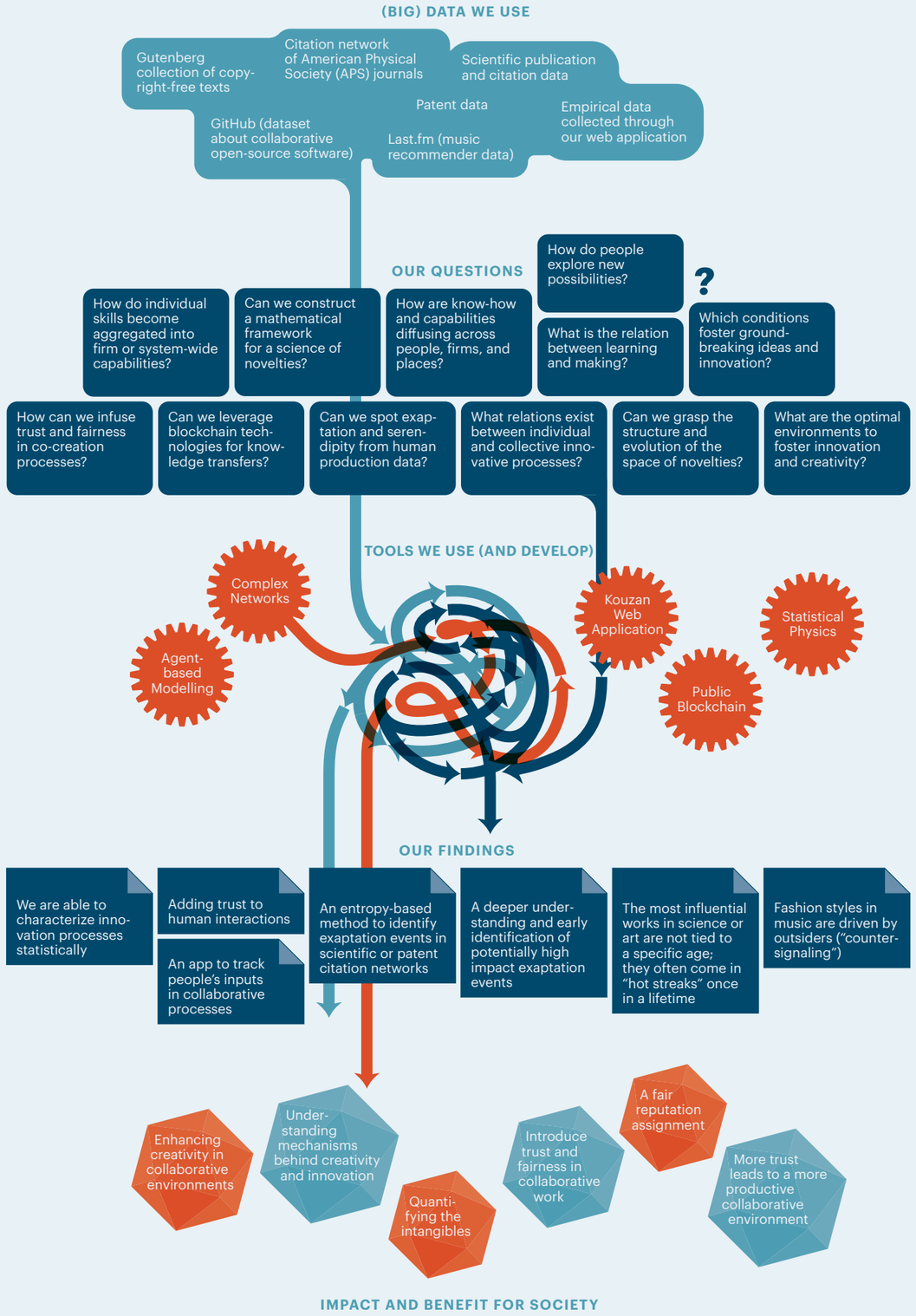
Innovation & Creativity

Where do great ideas come from? We are convinced there is a social component that can be described and maybe even predicted: certain processes that lead humans to be creative and generate innovations.

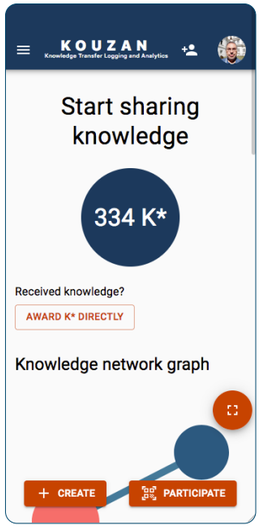
One of our main research topics is to find the underlying principles of creative and innovative processes, and the concrete conditions that lead to innovation.

We also want to trace individual contributions to innovations. This becomes increasingly important in times when new ideas are almost exclusively the result of cooperation. If individual contributions are properly recognized, trust and fairness in collaborative projects will be strengthened, be it in science, in music, or in other large collaborations.

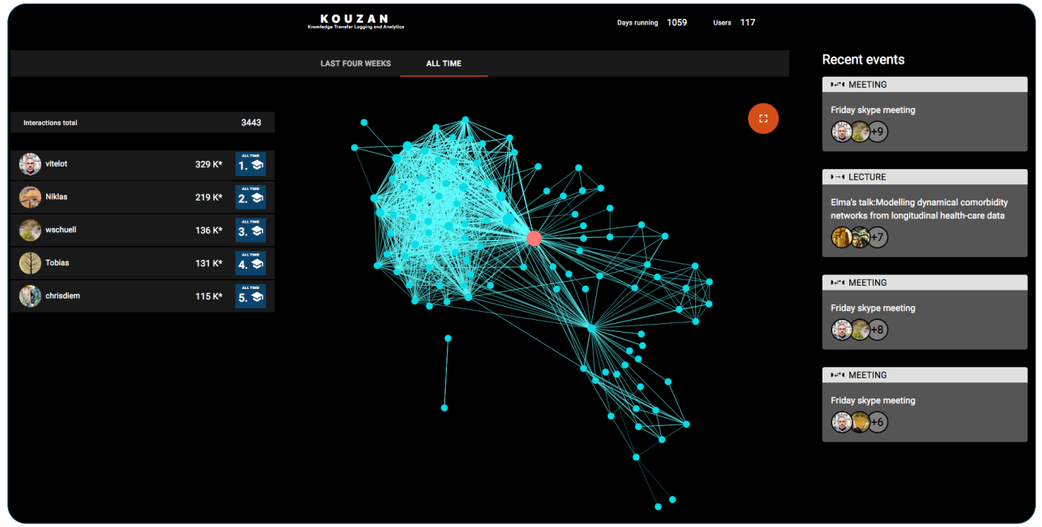
We develop methods based on the blockchain technology to document and quantify the individual bits that constitute the whole of collaborative work.



The Creative Input Tracker



KOUZAN app. The main page of the web application



Public display of the KOUZAN app, showing the graph of information flow between collaborators.

by Vittorio Loreto and Vito D.P. Servedio

Hub scientists developed an app that helps trace the knowledge transfer among people, thus documenting and correctly attributing the creative input of individuals to a joint project.

NOVELTIES AND INNOVATIONS

When we encounter something new in our daily lives, we experience the occurrence of novelties. Novelties may happen by chance or follow one after the other in a correlated stream of events.

While novelties are associated with individual experiences, innovations, on the other hand, refer to a more global view, where "the new" is experienced at a collective level: Primates evolved into homo sapiens; or the transistor paved the way to the integrated circuit and personal computers.

The characterization of innovations in their occurrence and prediction has offered challenges to humankind ever since. Without a doubt, our immediate actions are based on future expectations so that a thorough investigation and a deep understanding of the mechanisms behind the emergence of innovations—creativity and collaborative work—are key to achieving steady progress in our societies.

INFORMATION FLOW IS HARD TO MONITOR

More often, the emergence of innovations is supported by an underlying exchange of information, which might involve many actors.

Information is increasingly becoming one of the most important resources of our era, a real currency that determines our choices, as individuals and as a society. It represents the main resource we rely on in the very many small- and large-scale decision-making processes in our everyday lives. Despite its paramount importance for opinion propagation, creativity, innovation processes, marketing, policy making, etc., the information dynamics are not yet fully understood.

Information exchanges are hard to monitor and assess. In informal interactions, formal meetings, or brainstorming sessions, usually no digital monitoring is in place, making the actual transferred content difficult to grasp.

The impossibility to track knowledge transfers poses two problems. Unlike in former times, modern creative industries rely on complex creation processes, where many actors contribute chunks of content and a few key people make the whole process eventually converge into final products like songs, interactive scripts, videogames, screenplays, scientific articles, or textbooks.

The same is true when people collaborate to solve common problems. Brainstorming often proceeds through an apparently incoherent cloud of ideas, possibly converging into one optimal solution. This process is made cumbersome by the lack of effective tools to trace and retrieve all emerging sets of possibilities, a framework that favors the creative impetus of all actors.

WHERE DO IDEAS COME FROM?

The second problem concerns the intellectual property rights of information or knowledge producers. Giving credit to all the contributors to a specific process fairly is hindered by the lack of tools to timely and reliably assess the amount of knowledge transfer. Very often the question of who did what, when and under which circumstances, cannot be answered satisfactorily and is delegated to external authorities who may not have the full picture or, even worse, may be biased. To address these points, the CSH and SONY-CSL Paris have been collaborating on the so-called KOUZAN project.

KOUZAN: TRACING KNOWLEDGE TRANSFER IN HUMAN COLLABORATIONS

Together with theoretical aspects that characterize the interplay of innovations and information flows, the KOUZAN project addressed technical aspects by developing a web application capable of recording human interactions involving knowledge transfer.

The KOUZAN app was designed to keep track of knowledge transfers in a collaborative environment. Its key feature is the monitoring of all events where two or more peers exchange information. Examples range from conversations, presentations, and group meetings to any kind of co-creation processes in person or online.The KOUZAN app allows these events to be tracked on multiple channels to provide an extensive overview of information flow in large institutions or corporations with many different interacting sectors.

DEALING WITH INTELLECTUAL PROPERTY RIGHTS

Modern businesses and organizations rely on complex collective processes where the workload is subdivided into tasks assigned to individuals. Often dependent on specific knowledge, these processes cannot be carried out independently, creating a network of dependencies. In these cases, the efficiency of collective processes depends on a complex communication pattern among all involved actors.

To improve this, one should theoretically look at the organizational chart, the position and job descriptions. However, the organizational chart does not accurately reflect where to find knowledge. Much implicit and organizational knowledge essential to a functioning operation lives in employees' heads—where it cannot easily be located—and is transmitted informally.

Almost all organizations have people who can be considered experts or advisors in certain areas, even though this fact is not documented anywhere and is unknown to people outside of their immediate environment. At the same time, connecting different groups and transmitting knowledge from one location in the organization to another is often not limited to management but carried out by multiple actors.

Should any of these actors leave the organization, problems can arise quickly. Large amounts of knowledge can be lost, often without the management being aware of it. If connections between groups are lost, they become detached and lose their synergies. The KOUZAN app was also designed to foresee and prepare for such events.

KOUZAN also addresses the problem of the intellectual property rights of information or knowledge producers. Interactions recorded by the app are also encoded and recorded in a public blockchain. Users can then access their records at any time to provide proof of their contributions. All in all, this guarantees censorship resistance and trust.

Fashion Styles: It's All About Protesting

Give our scientists data, and they will find an answer to a century-old debate: Why do new styles develop?

Coffee breaks often trigger new research. When Robert Kreuzbauer, a marketing expert at the University of Surrey, expressed his hunch that new styles are driven by protest, CSH's Stefan Thurner offered to test this idea with data. "Big Data analytics can be used to come to a better understanding of the many layers of complex dynamics in human society," Stefan is convinced.

The scientists decided to go for musical styles. They derived data on almost eight million musical albums, starting in the '50s, from Discogs, a crowdsourced online music database. Discogs users provide detailed information on albums, such as artists or instrumentation, and assign each record to one or several of the 422 different musical styles.

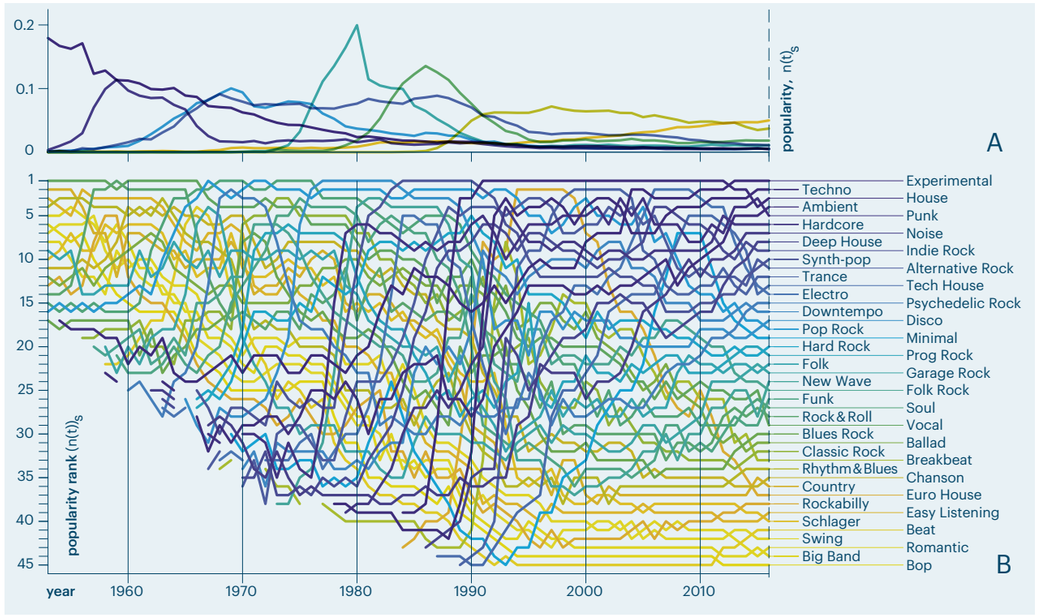
A SLAP IN THE FACE

The researchers saw Robert's hypothesis confirmed: Fashion cycles in music were indeed driven by outsider groups. "Outsiders challenge the dominant music style by strongly contrasting the preferences of the current elite," says Stefan, "for instance, by using different instrumentation or new rhythms." The scientists defined elites as social groups with disproportionate access to certain resources; in music, it is those people who dominate the most popular music style at a given time. Scientifically, such elite competition in the form of opposition is called counter-signaling. In other words: With a new style, music producers try to slap the old one in the face.

NIRVANA VS. QUEEN

The grunge rock of Nirvana, for instance, thumbed its nose at the highly polished stadium rock of the '80s with bands like Queen or Guns N' Roses; punk was a counter-signal to the hugely popular soft rock of the '70s with musicians like Elton John, Simon & Garfunkel, or Tina Turner leading the charts. Once the new style is adopted by a sufficiently large number of followers, its representatives become the new elite and the cycle starts from the beginning.

P. Klimek, R. Kreuzbauer, S. Thurner, **Fashion and art cycles are driven by counter-dominance signals of elite competition: Quantitative evidence from music styles**, *The Journal of the Royal Society Interface* 16 (151) (2019)



(Figure) (**A**) For each year, the most popular style is identified. Its popularity is shown over the entire observation period. The first cycle is given by Vocal music (strong focus on voice), followed by Rock & Roll, Pop Rock, Soul, Disco, Synth-pop, House, and Experimental music. (**B**) Most styles enter with a rather low popularity that they maintain over a number of years. These phases are eventually followed by a rapid increase in popularity. (Only those styles that were among the five most popular ones in at least one year are shown.)

Optimizing Creative Teams

Give our scientists data, and they will find an answer to a century-old debate: Why do new styles develop?

Modern communication technologies have made a completely new kind of creative work possible. Whether it is Wikipedia, coding new computer games, developing screenplays, or songs, many creative processes today are the product of a crowd. Individuals only contribute chunks of content to the big picture.

Bernardo Monechi (Sony Computer Science Lab Paris), Giulia Pullano (INSERM at the Sorbonne in Paris) and CSH's Vittorio Loreto wanted to know under which conditions such creative communities are most productive. The team designed an open-ended experiment to identify key ingredients of successful working groups.

They set up three stations with white Lego bricks at the KREYON Days exhibition in Rome. Each station had an assigned topic: "spring," "pyramids," and "Halloween." Visitors to the exhibition could freely contribute to the collective development of one, two, or all of the Lego artworks, either by building, destroying, or modifying some of their parts.

The scientists wanted to document the time and pattern of the individual's interactions, as well as his or her contributions to a station. Therefore, they equipped all participants of the experiment with special sensors when they entered the working area. These Radio Frequency Identification (RFID) sensors with a 20-second time resolution recorded an interaction of two people when they stood in front of each other within one meter for at least 20 seconds. The sensors also documented the time spent at each of the tables.

"The constant monitoring shows us the dynamics of social bonds between people," explains Vittorio. These social bonds continuously form and break away, leading to a constant restructuring of the working teams. In parallel, infrared depth sensors monitored the evolution and the volume of each of the Lego artworks. This allowed accurate real-time 3D reconstructions of the growing and changing constructions.

In total, around 600 people participated in the experiment

KEYS TO SUCCESSFUL CONSTRUCTING: COMMITMENT AND SOCIAL INFLUENCE

The researchers were able to identify some components of successful working teams. "Larger teams with committed people—that is, people focusing primarily on one station—build more successfully," says Vittorio. The higher the commitment and the bigger the team, the higher the growth rates.

"We also looked at the role of socially influential people in this dynamical interaction network," Vittorio continues. Such influencers are defined as information spreaders within the social network of the experiment, analogue to virus spreaders during an epidemic. Influencers were identified through a simple information diffusion model, the SI (Susceptible-Infected) model. Every individual is associated with observable fractions of interaction. This allows the scientists to quantify his or her level of influence. When more influential people gathered at a time, the artworks grew faster.

NEW PEOPLE BRING IN NEW IDEAS

On the other hand, it also seems to make sense to have a certain number of people who have not interacted much previously. The researchers call them "weak ties" in a given social network. "Some experts argue, that 'weak ties' in social networks are the most critical drivers of collective creativity," Vittorio points out. They contribute to a constant inflow of new information. Hence, too many weak ties could prevent an efficient communication between individuals.

"Our study shows that there exists an optimal fraction of weak ties in a working team that maximizes the building efficiency," maintains Vittorio. This optimal ratio highlights a subtle interplay between the strategies of exploiting (retracing old steps) and exploring (experimenting novelties).

The scientists sum up their observations in one sentence: "The best way to assemble a team for a creative task is to have it large, full of firmly committed, possibly influential individuals, and with a right balance between weak and strong ties," the scientists write.

B. Monechi, G. Pullano, V. Loreto, **Efficient team structures in an open-ended cooperative creativity experiment**, *PNAS* 116 (44) (2019) 22088–22093

SELECTED RESEARCH FINDINGS

A Thousand Aspects of Society

Democratic values. Social dynamics. Opinion formation. Emotions or bias in the web... Hub scientists work on a broad range of socially relevant issues with a large arsenal of methods, data, questions, and goals.

The functioning of civil society is based on certain rules, such as collective democratic decisions. As soon as rules change, people change their behavior—and this in turn changes the network structure of civil society. The science of complex systems offers new insights into how social processes work and into the difficulties of controlling and balancing interests.

CSH scientists look at socially relevant issues from various perspectives:

We investigate (collective) emotions in digital environments.

We seek to find rules that explain why some societies are resilient, while others are prone to collapse: We want to identify possible societal tipping points.

We focus on a better understanding of the way the Internet and social media work and impact societies. How can democratic and humanistic values be saved in times of digitization?

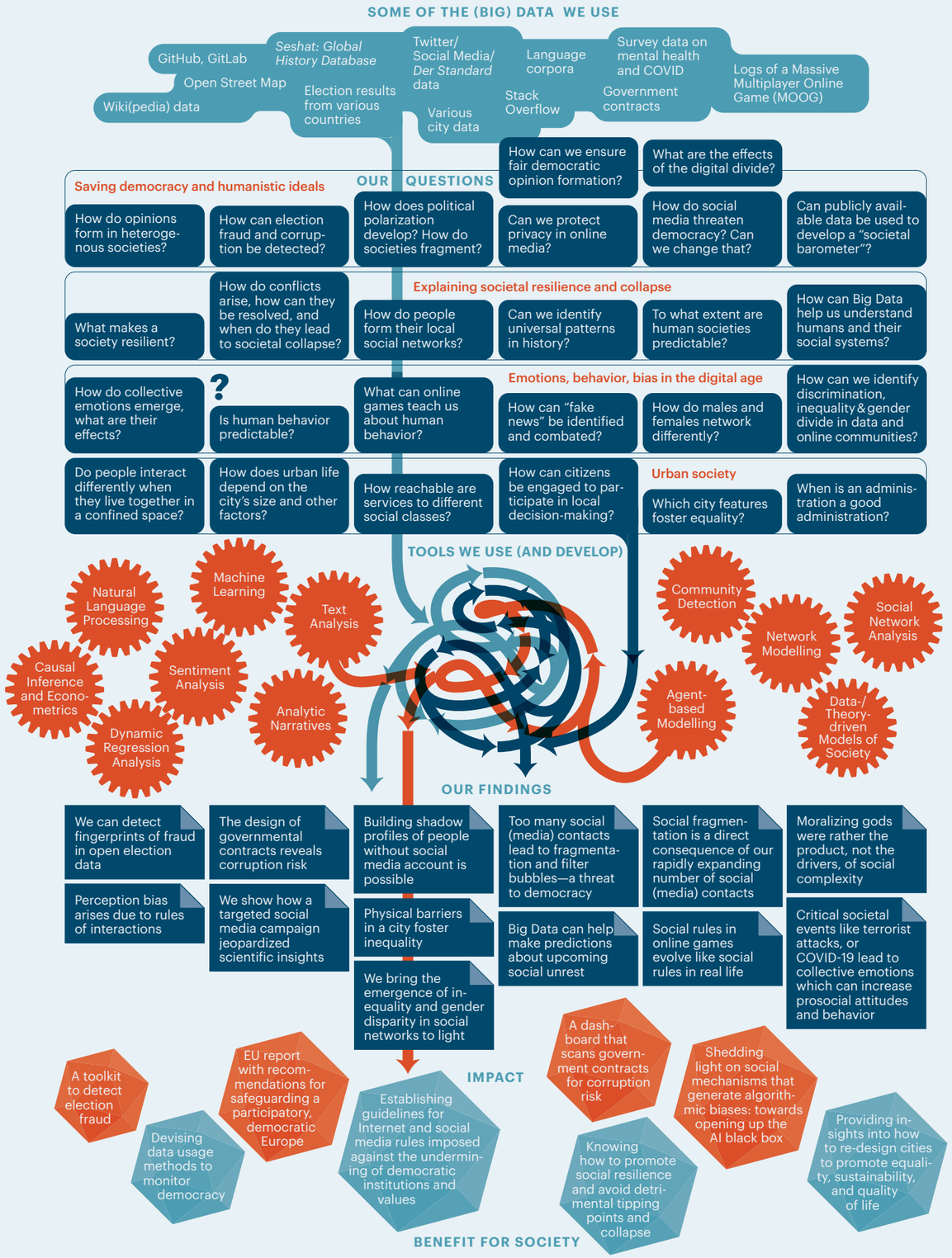
A new research team will be examining fairness and bias in Artificial Intelligence and the Net, another one focuses on various aspects of a societal megatrend: urbanization.

We even cover the development of societies through the ages. With *Seshat: Global History Database* we are aiming at rigorously—and quantitatively—testing hypotheses about the rise and fall of large-scale societies across the globe and human history.

Once we understand how rules emerge and govern a society: Shouldn't it then also be possible to understand social behavior, networks, and systems in an experimental, quantitative-predictive way?

Could large datasets and rigorous methods help us to turn social sciences and the humanities into a "science" in the Anglo-American sense of the term? Some Hub researchers do indeed believe so.

In one way or another: Our overall aim is to find out how societies evolve in a favorable manner, that is, resiliently, peacefully, democratically, and sustainably.



Shadow Profiling

Social Media & Democracy

It is easy to create a shadow profile of people who do not have a social media account themselves: only by using information their friends unveil.

Data privacy is a major concern in today's Internet use. Some people are worried enough not to use social media to protect their private sphere. Possibly in vain, as research by CSH's David Garcia suggests. With data recovered from Friendster, a social network that got wiped out when Facebook appeared, David showed that the communication of friends can improve the estimation of sexual preferences of people who were not on Friendster themselves.

His findings back the so-called "shadow profile hypothesis," which maintains that it is possible to profile people who don't use social media simply by putting together the indirect information provided by their friends.

"Without oversight or collective control mechanisms, individuals have little power to ensure that they are not being profiled without their knowledge or consent," states another paper which tested this hypothesis with Twitter data. David and colleagues constructed a dataset with more than 150 million tweets of 1,000 users and their friends. The data included biographical and location information, as well as bidirectional friendship links.

And again: Information shared by users inside Twitter enabled the location of individuals outside the social network to be predicted. Moreover, it considerably raised the predictability of the biographical information of non-users. This means the very moment we've got friends communicating about us on social media, we are open books to data leeches.

"I don't claim that shadow profiles exist," David concluded, "but if companies are up to creating them, they won't have problems doing so."

D. Garcia, **Leaking privacy and shadow profiles in online social networks**, *Science Advances* 3 (8) (2017) e1701172

D. Garcia, M. Goel, A. K. Agrawal, P. Kumaragurum, **Collective aspects of privacy in the Twitter social network**, *EPJ Data Science* 7 (3) (2018)

Hub researcher David Garcia contributes to influential EU Report on *Technology and Democracy*.

On October 27, 2020, the EU Science Hub (the European Commission's science and knowledge service) released a large report aiming to "help citizens, civil society and policy-makers make sense of the impact the online world is having on our political decisions, and identify actions to safeguard a participatory, democratic European future," according to an accompanying text. One of the leading authors was Hub researcher David Garcia.

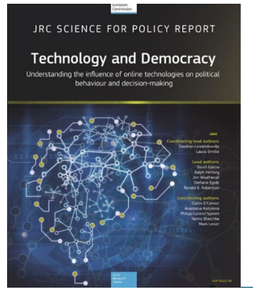
"When it comes to online media, we are like early societies that just founded cities," David explained after the release. "They didn't yet know that they would need fire departments, police, or mayors. They would only find out over time." The same applies to the brave new world of social media which turn out to be more than challenging for societies and democratic institutions.

The report adopts a behavioral psychology perspective, arguing that social media change people's political behavior. David has contributed to the chapters on the attention economy, renegotiations of privacy and personalization, or the architecture of social media platforms, amongst others.

Fingerprinting Electoral Fraud

Specific actions the report recommends include banning microtargeting for political ads, establishing transparency rules so that users understand how an algorithm uses their data and to what effect, or requiring online platforms to provide reports to users showing when, how, and which of their data are sold.

"This report was a big deal for the Commission and will directly influence EU law," says David. That's why the authors put huge effort into making the text accessible to everyone by using an easy language and a lot of examples.



S. Lewandowsky, L. Smillie, D. Garcia, R. Hertwig, J. Weatherall, S. Egidy, R. Robertson, C. O'Connor, A. Kozyreva, P. Lorenz-Spreen, Y. Blaschke, M. Leiser, **Technology and Democracy: Understanding the influence of online technologies on political behaviour and decision-making**, EUR 30422 EN *Publications Office of the European Union*, Luxembourg (2020)

A combination of statistical methods developed at the Hub can help uncover election irregularities and relate them to specific forms of malpractice.

Fair and free elections are at the core of democracy. However, a few hundred election observers cannot cover thousands of polling stations. Especially remote areas and smaller towns and villages are rarely monitored and thus prone to all kinds of electoral fraud. A research team led by Hub scientists introduced a new combination of statistical methods than can help uncover irregularities and relate them to specific forms of malpractice, including subtle intimidations like voting booths without curtains or extensive police presence near polling stations.

The "tool kit" further enables an estimate of whether the electoral fraud was strong enough to change the results of a vote. "Our method is fast, cheap, and easy to use," explains Peter Klimek, one of the authors. "The only input we need is election results." Usually, such lists are provided online within hours after an election. "Our tests show a very specific pattern: the fingerprint of the poll," Peter points out. These fingerprints show places where manipulation can be excluded or hotspots where it occurred with high probability.

FRAUDULENT POLLS IN TURKEY

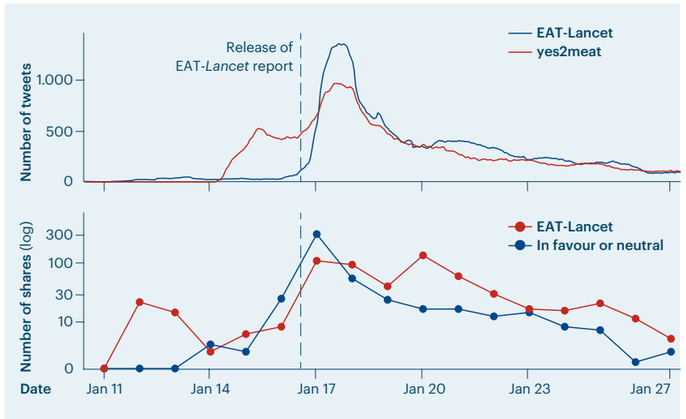
In Turkey, for instance, the researchers found several districts with problematic fingerprints right after the constitutional referendum in 2017. Recep Tayyip Erdoğan used the referendum to replace the Turkish parliamentary system with a presidential one. The highly controversial referendum was followed by an equally disputed snap election in June 2018 that installed Erdoğan as president with wide-ranging powers and his AKP as the ruling party in parliament.

FAIRNESS OF ELECTIONS IN THE DIGITAL AGE

Systematically utilized for election monitoring, the Hub method could help detect, or even prevent, unlawful voting throughout the world, the scientists are convinced. "We offer a simple and cheap method as an ideal extension to common election observation," states CSH's Stefan Thurner. "Organizations like the OSCE are invited to catch up with the digital age and use the new tools of the 21st century."

P. Klimek, R. Jimenez, M. Hidalgo, A. Hinteregger, S. Thurner, **Forensic analysis of Turkish elections in 2017–2018**, *PLoS ONE* 13 (10) (2018) e0204975

Pro-Meat Attacks



(Upper Graph) Time series of the number of tweets for each term in a 24-hour rolling window over the first weeks after the EAT-Lancet launch (Jan 11–27, 2019). **(Lower Graph)** Daily number of link shares to pages against and in favor of the EAT-Lancet Commission.

A social media campaign against academic research related to healthy diets may have influenced social media audiences more than communications from research organizations.

In January 2019, the prestigious journal *The Lancet* urgently called for reduced meat and dairy consumption to improve health and environmental outcomes. The report "Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems" called for a "planetary health diet" and received positive media coverage throughout the world. However, an analysis of social media campaigns by CSH's David Garcia and colleagues on Twitter shows that days before its launch, online pro-meat advocacy began to consolidate around the hashtag #yes2meat. In the following months, tweets attacking the report surpassed balanced communications, reaching 26 million people (compared to 25 million from academics and others promoting the research) despite having fewer followers.

The analysis of 8.5 million tweets by 4,278 Twitter users found that the digital countermovement was organized days ahead of the official launch of the EAT Lancet report, allowing the diffusion of critical and, at times, defamatory information from social media and alternative media platforms about the report. Negative sentiments and information on Twitter surpassed the balanced communication about the report from conventional media outlets, *The Lancet*, and science institutions involved in the scientific work, generating a clear digital backslash and the creation of a #yes2meat movement. This backlash was not driven by bots, but by users mainly from the US, UK, Australia, and Europe.

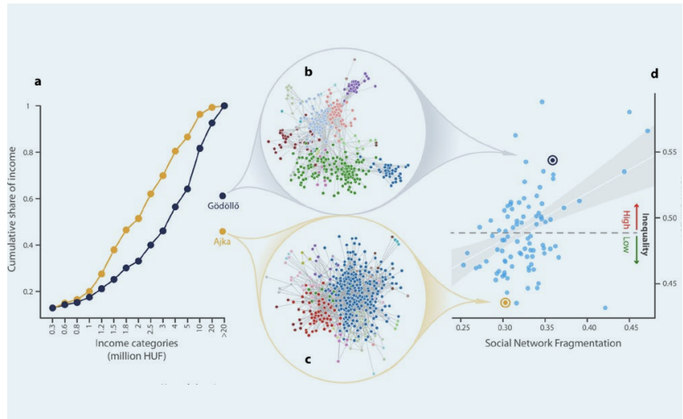
SCIENCE COMMUNICATION MUST HAVE AN EYE ON SOCIAL MEDIA CAMPAIGNS

It was a clear and successful digital backlash to insights produced by ambitious and high-profile scientific teams—reason for alarm bells ringing in every research institution. "It is critical to understand information dynamics of consumers and advocacy groups in the digital world," says David. "This study shows that scientific communication in social media is much more complex than through traditional mass media."

As social media are such an integral part of the conversation on and with science today, research organizations clearly need to do more to manage online advocacy and disinformation campaigns. Tools like those used for this analysis could help in the future to better understand the public impact of scientific findings.

D. Garcia, V. Galaz, S. Daume, **EATLancet vs yes2meat: the digital backlash to the planetary health diet**, *The Lancet* 394 (10215) (2019) 2153f

City's Shape & Inequality



Income inequality correlates with social network fragmentation in towns. Data from two Hungarian towns, i. e., Gödöllő (b) and Ajka (c), show that economic inequality, expressed by the Gini index, is higher in Gödöllő, where social networks are strongly separated. Urban geographies turn out to play a key role in this relationship.

Geography can become a root cause for inequality when cities are built in a way that fragments social networks.

One promising approach could be to look at the design of a city, according to research with real-world data.

An international team of scientists, including CSH's Johannes Wachs and János Kertész, show that urban planning directly influences the formation of social networks in a city and subsequently the socio-economic equality or inequality of its citizens.

"We know how important social networks are for our social and economic outcomes," Johannes explains. Social relations provide individuals with essential access to resources, information, economic opportunities, and other forms of support. In towns with more evenly distributed social networks, the economic inequality tended to be much lower than in towns with highly fragmented social networks, they show in a study. The scientists even found a vicious cycle: The higher the fragmentation of social networks, the higher the income inequality in a town over time was.

THE WRONG SIDE OF THE TRACKS

But where does such fragmentation come from? The researchers argue that one root cause lies in geography. To test their hypothesis, the complexity scientists used a large dataset from Hungary with two million individuals from about 500 towns. The data were retrieved from iWiW, a once—and before Facebook—very popular social media platform used by nearly 40 percent of the Hungarian population.

"Urban sociology research says that people cannot easily build social ties when they are separated by large physical obstacles such as rivers, railways, highways, or walls," Johannes points out. "It was impressive to see this confirmed in our data. We found evidence of strong physical boundaries in a city just by looking at its social network."

CITY DESIGN AND INCOME GO HAND IN HAND

"We hypothesized—and confirm it with our study—that if valuable ideas and information cannot float freely through a city because that city is physically fragmented, which in turn causes social fragmentation, we will see inequality. We clearly see how strongly geography and income inequality are related," says Johannes.

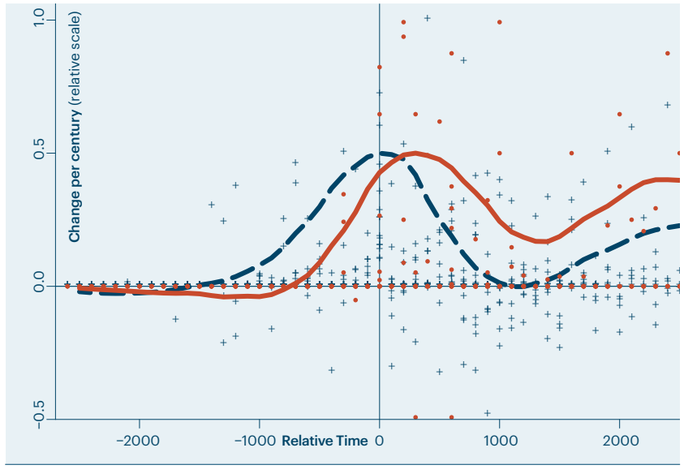
Of course, social networks do not form in a vacuum. A lot of different mechanisms influence with whom we are in regular contact. For instance, humans tend to befriend similar people ("homophily"). Friends of friends also show the tendency to become friends, too ("triadic closure"). Yet, the iWiW data found geographic indicators of towns as an additional strong predictor of fragmentation in social networks.

A CHANCE FOR CITY PLANNERS

"You hardly can change social networks directly via public policy. You cannot force people to interact if they don't want to," says Johannes. Nonetheless, towns and cities frequently make decisions about the built environment that will have effects on how their inhabitants can meet and interact. "If these decisions reflect on our findings, we predict that cities will have fewer problems with inequality in the future."

G. Toth, J. Wachs, R. Di Clemente, A. Jakobi, B. Sagvari, J. Kertész, B. Lengyel, **Inequality is rising where social network segregation interacts with urban topology**, *Nature Communications* 12 (1127) (2021)

Seshat: Global History Databank



Social complexity and moralizing gods. Charting when societies saw an increase in social complexity (blue) and the adoption of moralizing religious thought (brown), relative to a moderate complexity (relative time=0).

Seshat allows researchers to test theories about human societies using a large archive of curated data—a goldmine of rich historical data for studying cultural evolution.

Until recently it has been almost impossible to distinguish between cause and effect in theories of social evolution, as standardized quantitative data from throughout world history were missing. To address this problem, *Seshat: Global History Databank* was founded in 2011. The multidisciplinary open-access database is currently assembling about 200,000 records on social complexity, religious beliefs and practices, and other characteristics of over 500 past societies, spanning 10,000 years of human history, beginning with Neolithic Anatolians who lived in what is today Turkey in 9600 BCE.

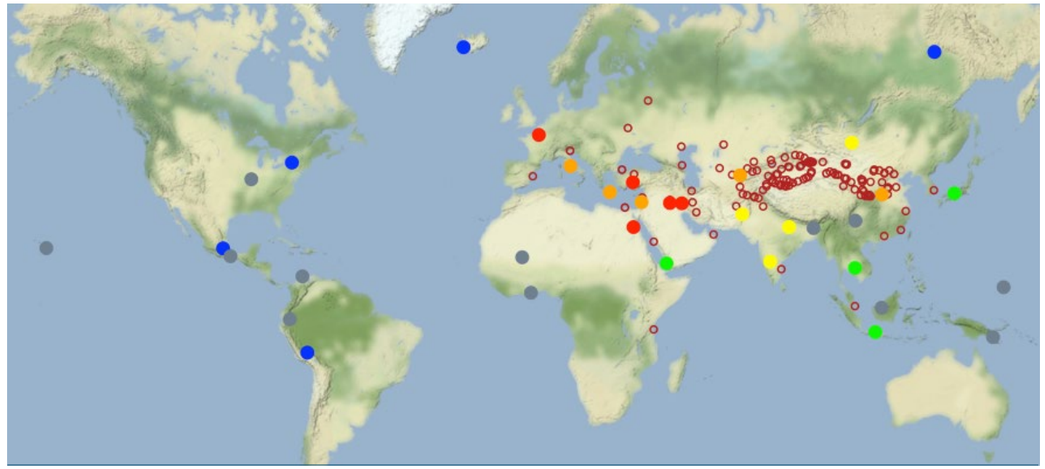
Seshat is the most comprehensive—and constantly growing—collection of prehistoric and historical data to date, with hundreds of variables relating to social complexity, religion, warfare, agriculture, and other features of human societies that vary over time and space. The dataset allows researchers to put theories about human history and societal dynamics to the test, including competing theories of how and why humans evolved to cooperate in large-scale societies.

One of *Seshat*'s founders is Peter Turchin, who has led the Hub's research on "social complexity and collapse" since 2020. Through collaboration between anthropologists, historians, archaeologists, mathematicians, computer scientists, and evolutionary scientists, Peter and his team seek to uncover the forces that drive societies to coalesce and expand, as well as those that lead to decline and fracture. This is a huge topic involving multiple interacting factors, from economic and political systems to technological development to ideological and religious thought and practice.

DYNAMICS OF SOCIAL COMPLEXITY

The rise, spread, and fall of societies has occupied scholars and thinkers for centuries. A wide range of theories has been offered, focusing on various factors from the ability of elite populations to capture and institutionalize economic and social inequities, to the organizational demands of collective goods such as irrigation works, to the pressures of inter-group competition.

One of the first successes of this research team was in documenting increases in social complexity, a complex composite quantity including aspects such as the society's size in terms of territory and population, its administrative institutions, and informational and economic complexity, among other factors. The *Seshat* team set out to explore these dynamics among hundreds of societies from around the globe and over the very long term.



Location of 35 regions in the *Seshat* sample, colour-coded by whether societies in those areas experienced intense military competition, connection to a growing exchange network, and increases in social complexity very early on (red, orange), very late (blue, grey), or in the middle (yellow, green). Open red circles show nodes in the Silk Road, an early exchange network.

To their surprise, this data revealed that societies tend to take a fairly common path, seeing a variety of these complexity factors all rising—and falling—in step. Further, the team has begun to explore what drives these increases, finding that intense competition between societies as well as participation in information exchange networks provide a major push, increasing the scale and other aspects of complexity.

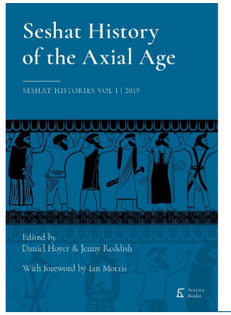
BIG DATA REVOLUTIONIZE THE STUDY OF HUMAN HISTORY

Interestingly, once societies have experienced these "jumps" in complexity, a host of other developments tend to appear.

For instance, another key wing of work by the research group investigates when, where, and, in particular, why we find moralizing religions, ideologies stressing egalitarian principles, and institutions constraining the authority of rulers being adopted—all hallmarks of modern social formations. Recent research shows that these developments tend to arise in societies only once they have reached a certain threshold of social complexity, not before and generally not without hitting that mark. These features seem essential for maintaining cooperation and cohesion at large scales, helping to keep societies from breaking apart.

Nevertheless, societies do at times experience crises, fragmentation, and even complete collapse. A focus of the Social Complexity and Collapse team at the Hub is to explore the external forces (e.g., conflict with other societies, global economic shocks, ecological disasters) as well as internal dynamics (growing inequalities, decline in well-being, rising polarization, and conflict among elite populations) that lead to periods of crisis and, more importantly, determine how severe outcomes will be.

"The *Seshat* Databank is an impressive example of how carefully curated data can revolutionize the study of human history," says Peter. "Being able to ask the 'Big Questions' about our shared past cannot only help explain how we got to where we are today, but can offer insight into where we're headed."



P. Turchin, H. Whitehouse, P. François, D. Hoyer, S. Nugent, J. Larson, R.A. Covey, M. Altaweel, P. Peregrine, D. Carballo, G. Feinman, V. Wallace, P.K. Bol, A. Korotayev, N. Kradin, E. Anderson, P.E. Savage, E. Cioni, J. Levine, J. Reddish, E. Brandl, A. Squitieri, **Explaining the Rise of Moralizing Religions: A Test of Competing Hypotheses Using the Seshat Databank**, *SocArXiv* (Preprint Nov 20, 2019)

H. Whitehouse, P. François, P. E. Savage, T. E. Currie, K.C. Feeney, E. Cioni, R. Purcell, R.M. Ross, J. Larson, J. Baines, B. ter Haar, A. Covey, P. Turchin, **Complex societies precede moralizing gods throughout world history**, *Nature* 568 (2019) 226–229

P. Turchin, D. Hoyer, A. Korotayev, K. Nikolay, S. Nefedov, G. Feinman, J. Bennett, P. François, H. Whitehouse, **Rise of the War Machines: Charting the Evolution of Military Technologies from the Neolithic to the Industrial Revolution**, *SocArXiv* (Preprint Dec, 2020)

D. Hoyer, J. Reddish (eds.), ***Seshat History of the Axial Age***, Beresta Books (2019)

Social Polarization & Fragmentation

Two Hub papers, two methodological approaches, two perspectives on one subject: Why societies become more and more polarized.

POLARIZATION

A Vicious Cycle

The extent to which people like or dislike each other affects their political views and vice versa.

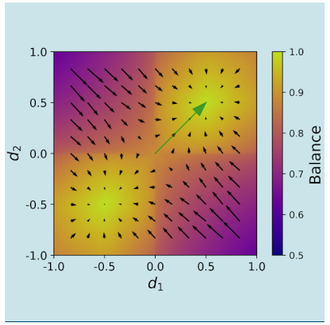
A certain degree of polarization of political opinions is considered normal—and even beneficial—to the health of democracy. Currently, however, conservative and liberal views are drifting apart. When too much polarization hampers a nation's ability to combat threats, this can be detrimental to a society. According to the "Weighted Balance Theory" (WBT) developed under Hub lead, the driving force for "hyperpolarization"—that is, the combination of extremeness and correlation—are social emotions.

HOW DO EXTREME POSITIONS EVOLVE?

"We feel high balance when dealing with someone we like and with whom we agree in all political issues," Simon Schweighofer, a former PostDoc at the Hub who now works in China, explains the approach. "We also feel high balance towards those we hate and with whom we disagree." This human tendency to maintain emotional balance was first described in 1946 by the Austrian-born psychologist Fritz Heider (who worked most of his life in the U.S. though) as Social Balance Theory.

Yet, when individuals disagree with others they like, or agree with others they dislike, "they will try to overcome this imbalance: They adapt their opinions in order to increase the balance with their emotions," Simon claims. Increasingly intense emotions and opinions gradually replace moderate positions until most issues are seen in the same—often extremely polarized—way as one's political allies.

This vicious cycle ultimately ends in total polarization, adds David Garcia. Not only do people then categorically favor or oppose single issues like abortion or same-sex marriage. "If they are pro-choice, they are at the same time highly likely to be for gay marriage, the legalization of marijuana, against nuclear energy and so on." A possible variety of opinions is reduced to black and white—the split between left and right we see everywhere.



The driving force behind "hyperpolarization," that is, a combination of extremeness and correlation, could be social emotions.

AN INTERDISCIPLINARY APPROACH

"Hyperpolarization has so far been overlooked in social theories on opinion formation," concludes Simon. The WBT—an interdisciplinary effort that integrates research in psychology, political science, and opinion dynamics into an overarching theoretical framework—offers a new perspective on the emergence of political conflict.

S. Schweighofer, F. Schweitzer, D. Garcia, **A weighted balance model of opinion hyperpolarization**, *Journal of Artificial Societies and Social Simulation* 23(3) (2020) 5

FRAGMENTATION

When Relationships Get Out of Balance

The phenomenal increase in our social (media) contacts inevitably leads to a filter bubble society—a fragmentation that is a real danger to democracies and the mastering of future challenges.

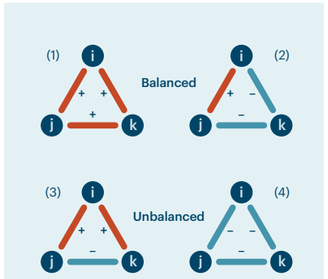
All of a sudden, democratic discussions and processes of reasonable opinion formation became difficult. One root cause seems to be "filter bubbles" that emerge just about everywhere in the Internet.

Hub PhD candidate Tuan Pham, Rudi Hanel, and Stefan Thurner, together with CSH External Faculty member Imre Kondor, wanted to find out why filter bubbles appear. They started with two classical sociological concepts that have been empirically tested in hundreds of studies over the past decades.

The first one is known as (social) homophily. It says that humans have a tendency to like and interact with other people if they are similar to themselves. "People are just happier when they do not disagree or argue with others," explains Tuan. "One can say: Like will to like." In order to avoid stress, homophily leads to opinions becoming more and more alike and aligned with each other within the group.

The second concept is the Social Balance Theory already mentioned in "Polarization". Put simply, it describes the fact that people are keen to ensure that their friends get along well with each other.

"We like to construct social triangles," Stefan points out and shows a simple figure of possible contacts in such a triangle:



Balanced and unbalanced relationships.

Red lines represent friendly and cooperative relations between individuals, blue lines are negative or hostile links. "We usually cope better with balanced relationships," says Stefan. In triangle 1, (i), (j) and (k) get along well. In triangle 2, (i) is on good terms with (j) but on bad terms with (k)—and observes that (j) and (k) dislike each other, too.

"What we absolutely dislike is when two of our friends don't get along," Stefan continues, as shown in triangle 3—not to mention triangle 4 where (i), (j), and (k) hate each other). As a matter of fact, such states of imbalance can be found much less frequently in societies.

For their simple model of a society, the researchers combined these two concepts with the physical principle of energy minimization. They apply the principle to societies, claiming that people generally seek the state of least social stress.

After doing so, their model showed two clearly separated social states: Either the society was cohesive, meaning there is cohesion and exchange, and cooperation can take place; or the society disintegrates from one moment to the other into small bubbles of like-minded people. While the like-minded get along well with each other, constructive communication across the bubbles is no longer possible. Society fragments.

TOO MANY SOCIAL CONTACTS LEAD TO PHASE TRANSITION

The change from cohesive to fragmented is abrupt, the model shows. What causes the tipping? Comparable with water, where specific temperatures make the difference between ice, liquid, or gas, the new theory of social fragmentation points to the number of contacts people have that lead to the tipping point for a phase transition from a cohesive to a fragmented society.

"I still remember the times my family had to share a phone line with other households," Stefan recalls. "Later, every household had a line, eventually every person had his or her own cell phone. Then came the smartphone, and boom! Suddenly we are connected all over the world at all times, and simultaneously through many channels." The Internet, smartphone use, and social media made our connections to others explode within a couple of years.

This is a problem for the well-being of individuals, simply because they can't stand too much disagreement, or even hate. "Disagreements in small groups, for example, a dispute with two people in an extended family of ten, are something we can handle quite well," says Tuan. "But if suddenly 20 out of 100 people are against me, I can't cope with it. I will start avoiding these 20, and rather stay within my own friction-free social bubbles."

If many people do that at the same time, the model shows the sudden shift described above: an automatic, inevitable fragmentation of the society. "If the sociological assumptions hold—and sociologists tell us they do—, this is as certain as a law of nature," Stefan is convinced.

DEMOCRACIES AT RISK

That could pose a huge problem to democracy, as well as to the management of the massive challenges ahead, such as finding ways to deal with climate crisis, economic transitions, or future pandemics. "If people stay within their bubbles and are no longer willing to leave their comfort zones, how are we, as a society, supposed to negotiate important issues? How are we supposed to reach compromises that are the basis of all democracy?" Stefan asks. We already got a foretaste of how real and potentially explosive this development is: The last two US elections or the increasingly rapid spread of conspiracy theories are telling examples.

But is there a way out? What do we have to do to save democracy?

"The most effective means would be to dramatically reduce our contacts again," Stefan says with a deep sigh, as he speaks of a change as far-reaching as a shutdown of Facebook, Twitter, YouTube, and all of the many other platforms we became so accustomed to. "I know, this is completely unrealistic," he adds. "But as a society, we really have to figure out how to deal with that matter, today rather than tomorrow." Otherwise, we risk the future of what our ancestors so hardly fought for through centuries: egalité, fraternité, and liberté.

T. M. Pham, I. Kondor, R. Hanel, S. Thurner, **The effect of social balance on social fragmentation**, *Journal of the Royal Society Interface* (2020) 20200752

SELECTED RESEARCH FINDINGS

Supporting the Green Transition

How can we manage to drastically reduce carbon burning and at the same time keep civil society well away from massive tensions and potential collapse?

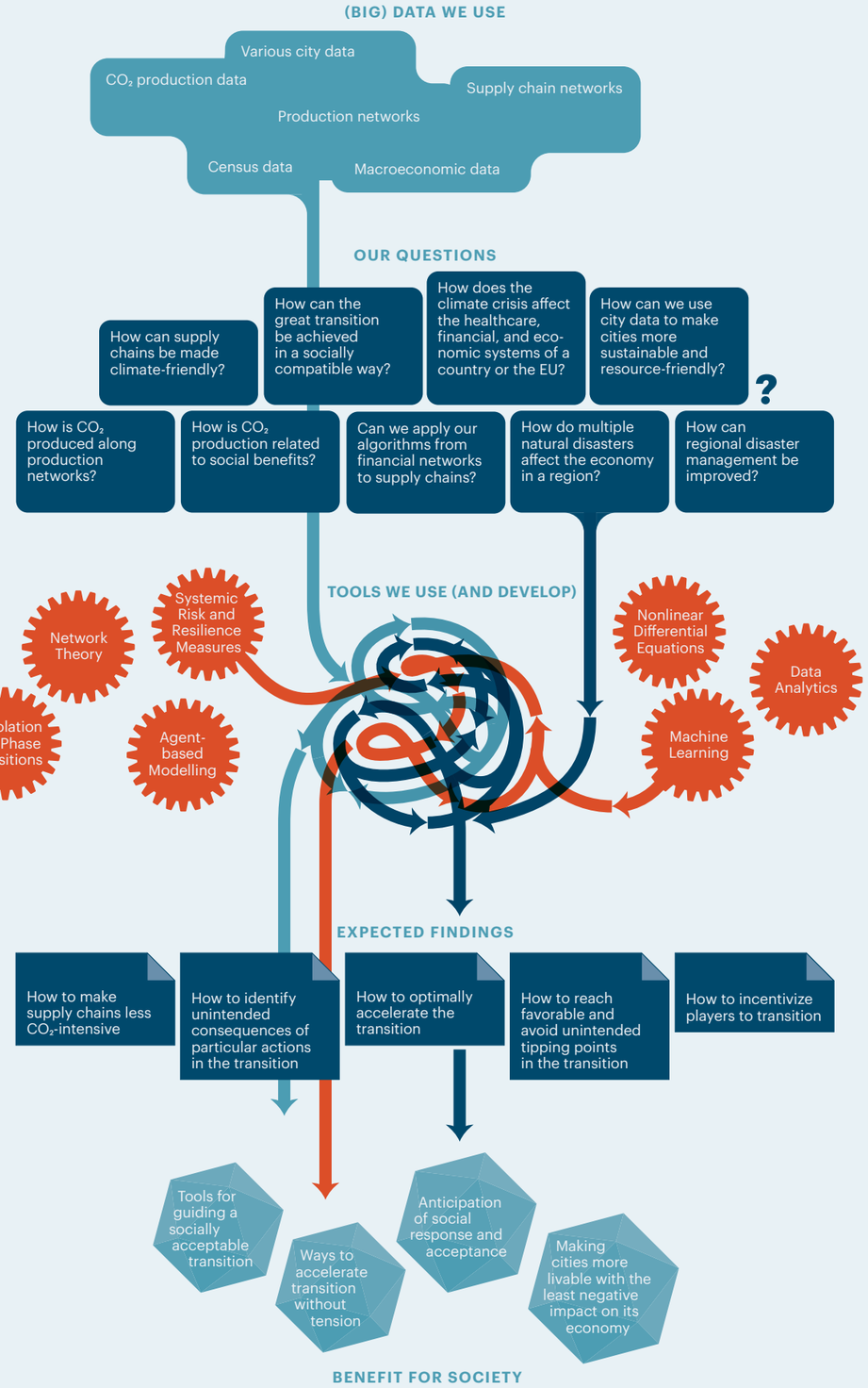
The environment, the economy, financial markets, social dynamics: Literally all parts in our socio-economic-ecologic system are closely intertwined and interdependent. We have to bear these interdependencies in mind—well, in the first place we have to start to understand their very nature and properties!—if we want to come to acceptable, and accepted, solutions for the great transition ahead.

To contribute to the huge endeavor of a green transformation, the Hub can use its expertise. For instance, we use supply chain data and agent-based models to measure the systemic risks of economies, the linkages between the economy and the financial sector, or the economy and environmental destruction.

We can also apply our new insights into how social dynamics and fragmentation processes work on the difficulties of controlling and balancing social interests.

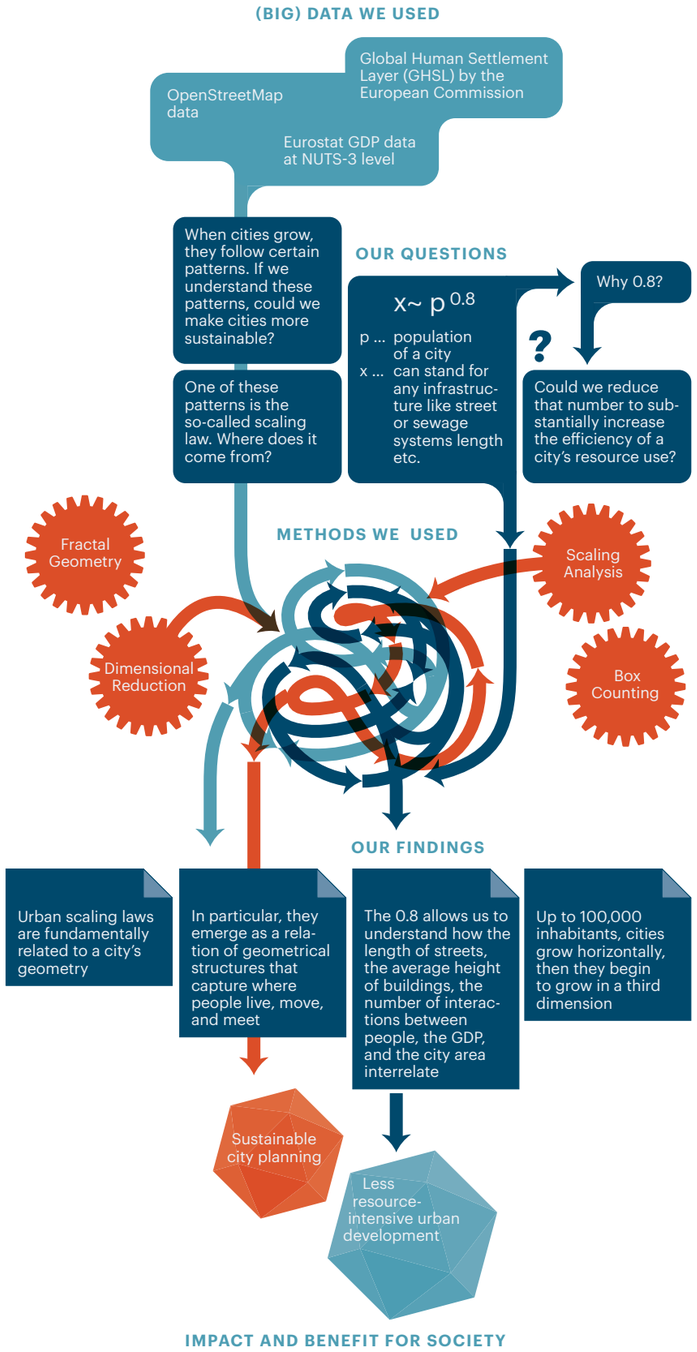
Based on our models, we aim to assist policy-makers by sharing viable possibilities, evidence-based decision tools, and strategies to better manage the necessary decisions to get through the transition wisely: namely to minimize greenhouse gas emissions while gaining and maintaining social acceptability by minimizing economic tensions that will arise as a consequence of the transition.

Hub scientists have just started to take a deeper look into the nature of production chain networks. Once their dependencies and the CO_2 flows in the system are systemically understood, we hope to make proposals on how to meaningfully rearrange production networks to become more sustainable and socially acceptable. We are designing an agent-based model that shows how emissions change when we restructure the supply networks through smart taxing, such that large greenhouse gas contributors transition rapidly and jobs don't get lost.



The City Formula

Worldwide, cities are expected to double in size until the end of the century. Many facets of city growth follow universal scaling laws. But where do these laws come from? CSH scentists offer a simple and elegant explanation: Urban scaling laws emerge from the 3D geometry of a city.



SCALING LAWS ARE EVERYWHERE

A characteristic feature of complex systems is that when they double in size, many of their parts do not. Typically, some aspects will grow by only about 80 percent, others by around 120 percent. The astonishing uniformity of these two growth rates is known as "scaling laws." Scaling laws are observed everywhere in the world, from biology to physical systems—and in cities. Yet, while a multitude of examples show their presence, reasons for their emergence are still a matter of debate.

Carlos Molinero and Stefan Thurner provide a simple explanation for scaling laws in cities: They derive them from the geometry of a city.

URBAN SCALING LAWS

One example of an urban scaling law is the number of gas stations: If a city with 20 gas stations doubles its population, say from 100,000 to 200,000, the number of gas stations does not increase to 40, but only to 36. This growth rate of about 0.80 per doubling applies to much of the infrastructure of a city. Other examples are the energy consumption per person or the land coverage of a town.

Since this growth of 0.8 is slower than what is expected from doubling, it is called sub-linear growth.

On the other hand, cities show more-than-doubling rates in socially driven contexts. Studies found for instance that people in larger cities earn consistently more money for the same work, make more phone calls, and even walk faster than small town inhabitants. This super-linear growth rate is around 120 percent for every doubling.

Remarkably, these two growth rates, 0.8 and 1.2, are showing up over and over again in literally dozens of city-related contexts and applications. But why?

IT'S ALL IN THE GEOMETRY

Carlos, who left the Hub in September 2020 but worked extensively on this during his time in Vienna, and Stefan are convinced that these scaling laws can be explained by the spatial geometry of cities. "Cities are always built in a way that infrastructure and people meet," says Carlos, an urban science expert who has also studied architecture. "We therefore think that scaling laws must emerge from the interplay between where people live, and the spaces they use to move through a city."

Stefan points out what makes the idea so special: "The innovative idea here is how the spatial dimensions of a city relate to each other."

FRACTAL GEOMETRY

To come to this conclusion, the researchers first mapped three-dimensionally where people live. They used open data for the height of buildings in more than 4,700 cities in Europe. "We know most of the buildings in 3D, so we can estimate how many floors a building has and how many people live in it," says Stefan. The scientists assigned a dot to every person living in a building. Together, these dots form sort of a "human cloud" of a city.

Clouds are fractals. Fractals are self-similar, meaning that if you zoom in, their parts look very similar to the whole.

Based on the human cloud, the researchers were able to determine the fractal dimension of a city's population: A number that describes the human cloud of each particular city. Similarly, they calculated the fractal dimension of cities' road networks.

"Although these two numbers vary widely from city to city, we discovered that the ratio between the two is a constant," Stefan says. The researchers identified this constant as the "sublinear scaling exponent."

A FORMULA FOR SUSTAINABLE URBAN PLANNING

Aside from the mathematical elegance of the explanation, the finding has potential practical value, the two complexity researchers emphasize. "At first sight, the appearance of such a constant looks like magic," says Stefan. "But it makes perfect sense if one takes a closer look: It's this scaling exponent that determines how the properties of a city change with its size—and that is relevant because many cities around the world are growing rapidly."

The number of people living in cities worldwide is expected to roughly double in the next 50 to 80 years. "Scaling laws show us what this doubling means in terms of wages, crime, inventiveness or resources needed per person—all this is important information for urban planners," Stefan points out.

To know the scaling exponent of a particular city could help urban planners to keep the gigantic resource demands of urban growth at bay. "We can now think specifically about how to get this number as small as possible, for example, through clever architectural solutions and radically different approaches to mobility and infrastructure construction," Stefan is convinced. "The smaller the scaling exponent, the higher the resource efficiency of a city."

C. Molinero, S. Thurner, **How the geometry of cities determines urban scaling laws**, *Journal of The Royal Society Interface* (2021)

SELECTED RESEARCH FINDINGS

Complex Visualization

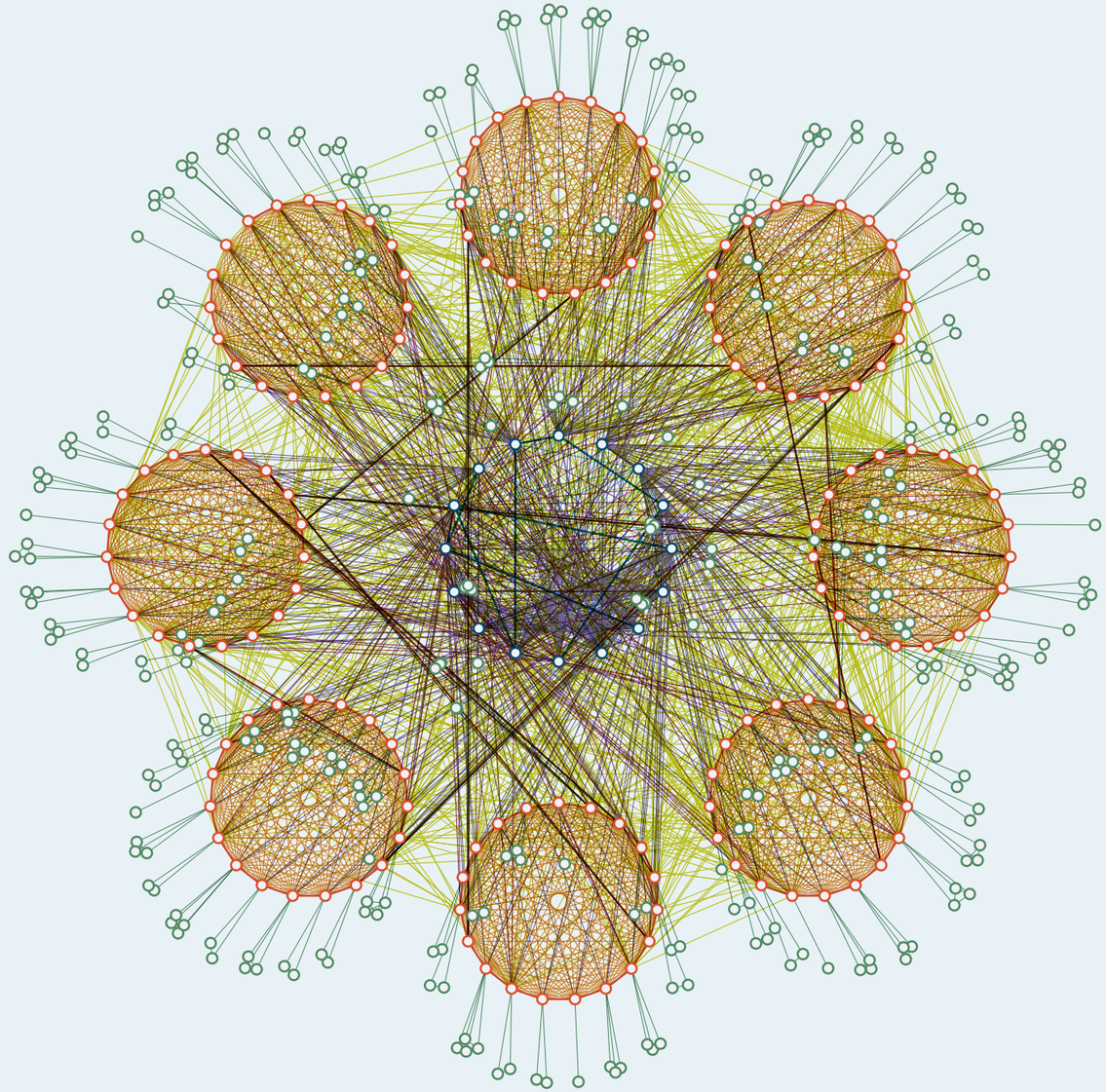
Hand on heart: How many pages in this publication have you actually read? In comparison: How many of its images did you look at?

Although somehow frustrating for the writer of these lines, she (the writer) as well as most of our scientists are well aware that humans are visual creatures. Without visualizations, scientific findings—and complexity research with all its formulas and technical terms even more so—remain abstract, the underlying models appear like black boxes. Visualizations aim to open these boxes up: The data are no longer just abstract but become transparent and comprehensible.

To reach that goal, we expand the well-known proverb, “A picture says more than a thousand words” by saying: “One interactive visualization says more than a thousand static graphs.”

Yeah: It’s all about interactivity! The communication direction of simple graphics is one-sided: The image tells a story, the viewer interprets it—end of story.

An interactive visualization, on the other hand, enables a dialogue with the picture: Viewers can address their own questions to the data, can be users of an application. They can pick the parts they are interested in and investigate them in more detail, learn more about what they see, and hopefully retrieve new insights from interacting with and manipulating the visualization (yes, we are haptic creatures, too).



CONTACT NETWORK IN AN ELEMENTARY SCHOOL

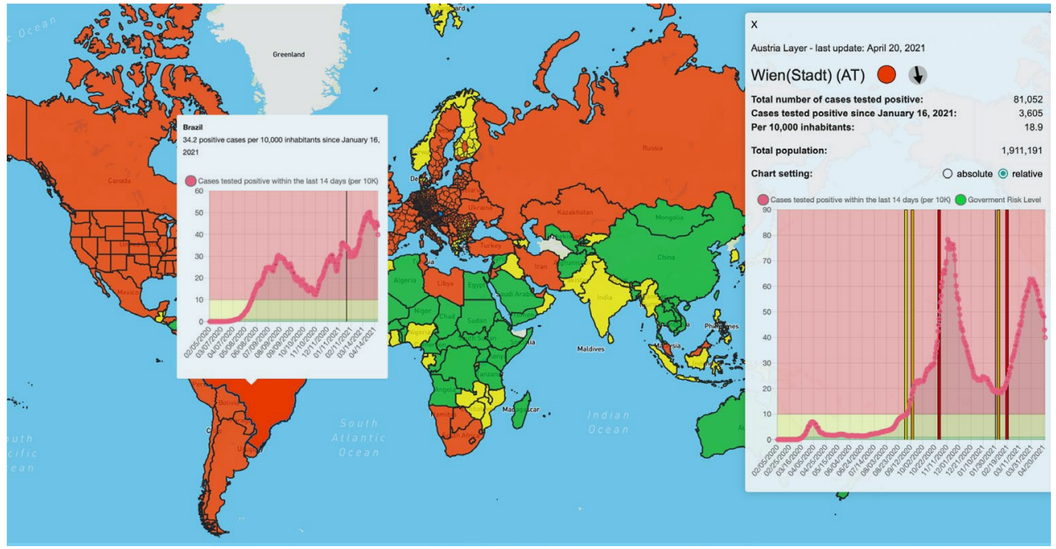
The contact network describes the type of contact between two people (pupil/teacher/household member). It is used for a school simulation developed by the Hub in order to determine the infection probability between an infected and a not-yet-infected person.

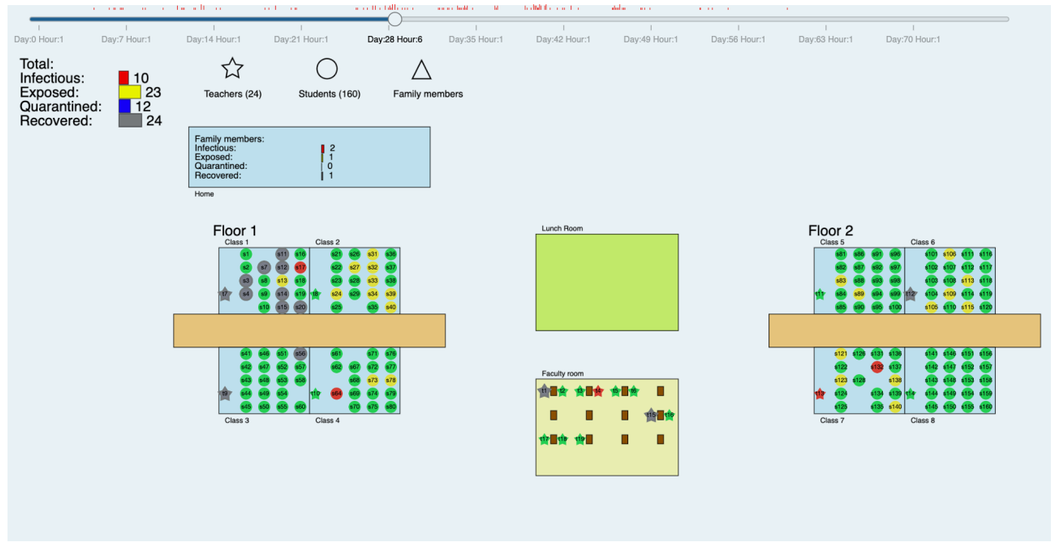
This school has eight classrooms (20 pupils each, in red) and 16 teachers (green). Individual household members are depicted in green.

Pupil
- Table neighbours & siblings
- Classmates
- Daycare mates

Teacher
- Joint teaching & supervision
- Acquaintances
- Conversation
- Teaching
- Daycare supervision

Family member
- Shared household





A MULTI-STEP PROCESS

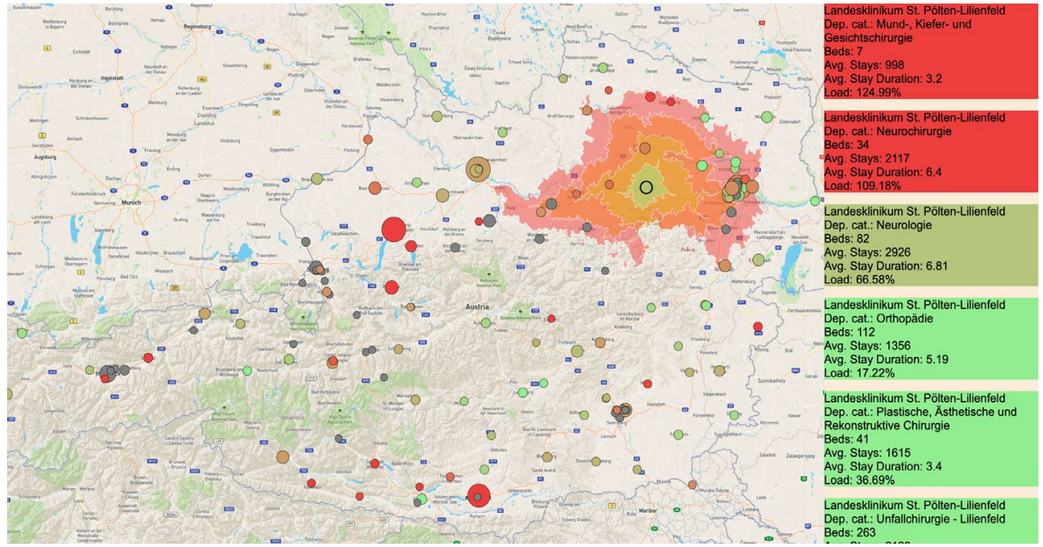
Visualizations are an essential tool in all stages of data science. In the beginning, they help our scientists to get an overview of often large and complex high-dimensional data, to find outliers and interesting regions to explore, and to create hypotheses that can later be tested with statistical methods.

During modelling, visualizations facilitate the verification of intermediate results. At the end of the process, they are the easiest way to convey results to peers, decision-makers, journalists, or the public.

As an individual research problem often requires individual visualization solutions, the vis team closely communicates with their fellow data scientists to determine which aspects of their data they are interested in, what they want to learn, and to whom they want to present the data in the end in order to realize their vis visions.

HIGH ROAD TO IMPACT

Since visualization is an enabling technology, the benefit and impact of this work is directly linked to the respective research projects. We could also put it the other way around: Our visualizations help our science to get impact.

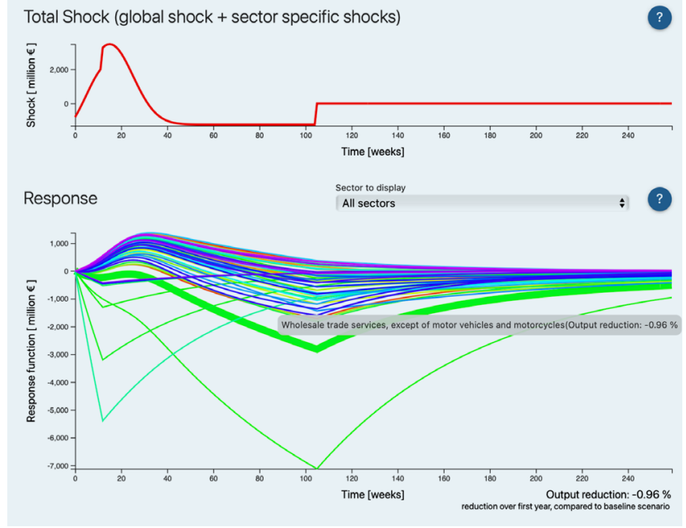


(Figure Top) Hospital availability. Using publicly available data, we charted a map of the hospital landscape in Austria that gives a rough estimate of each hospital department's workload based on the average number and duration of stays. We also show how reachable a hospital is by using publicly available routing services like Google Maps.

(Figure Right) With the interactive Economic Shock Explorer, the economic resilience of 65 Austrian economic sectors (resilience refers here to the ability to quickly recover from shocks) can be tested. To simulate the recovery from a demand shock, we use the sectoral inter-dependencies represented in a dynamic input-output model, which also takes the indirect effects of an economic shock into account. This allows the total effect on the economy to be quantified.

(Figure Top Left) CSH Corona Traffic Light. At the beginning of the COVID-19 pandemic, the Hub introduced a traffic light system to create public awareness for pandemic issues. The tool gained so much attention that the Austrian government later applied the traffic light metaphor to its own risk communication (see also pp. 28f).

(Figure Bottom Left) The "school tool." The Hub animation illustrates the daily schedule of students and teachers in pre-defined school settings. The color of a student or teacher indicates whether they are infected (yellow), infectious (red), susceptible to being infected (green), or immune (gray). Users can select different COVID-19 prevention measures to inspect their impact on a school.



In the past year, for instance, CSH visualizations helped in quantifying the resilience of the primary health-care sector in Austria, in enabling the comparison of comorbidity networks, or in assessing the risk of COVID-19 transmission.

Apart from supporting the other Hub researchers, the vis team also pursues its own basic research in visualization science, building upon the data and research tasks arising at the Hub. Essential questions are, for example, how high dimensional spatio-temporal data in a geographic context can efficiently be visualized, or what the benefits of virtual reality are for offering new perspectives into network analysis.

For more projects, check out the Hub's vis page: **http://vis.csh.ac.at**

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The first five years of scientific publications and papers by members and affiliates of the Complexity Science Hub Vienna.

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T. Reisch, P. Klimek, S. Thurner German

Kosten der Coronavirus-Epidemie 2020

CSH Policy Brief 1/2020 (Feb 7, 2020)

Der Ausbruch des Coronavirus 2019-nCoV wird China bis zu 300 Milliarden Euro kosten. Für Österreich belaufen sich die Ausfälle auf 1,1 Milliarden Euro. Betroffen ist vor allem der herstellende Sektor.

T. Reisch, P. Klimek, S. Thurner

Costs of the coronavirus epidemic 2020 for the Austrian economy

CSH Policy Brief 1/2020 (EN) (Feb 7, 2020)

The 2019-nCoV coronavirus outbreak will cost China up to 300 billion euros. For Austria, the losses amount to 1.1 billion euros. The manufacturing sector is particularly affected.

T. Reisch, P. Klimek, S. Thurner German

USA–China Handels-abkommen Jan 2020

CSH Policy Brief 2/2020 (Feb 7, 2020)

Das neue Abkommen zwischen China und den USA wird Deutschland mit Zeitverzögerung bis zu 8,7 Milliarden Euro pro Jahr kosten, Österreich bis zu 1,5 Milliarden Euro jährlich. In einigen wenigen Bereichen wird es auch positive Effekte für die Wirtschaft geben.

T. Reisch, P. Klimek, S. Thurner

Effects of the US-China Trade Agreement from Jan 2020

CSH Policy Brief 2/2020 (EN) (Feb 2020)

The new trade agreement between China and the USA will cost Germany, with a time lag, up to 8.7 billion euros per year, Austria up to 1.5 billion euros per year. In a few sectors there will be positive effects on the economy.

R. Hanel, S. Thurner German

Pooling von Coronavirus-Tests kann die Anzahl der getesteten Personen pro verfügbarem Test massiv erhöhen

CSH Policy Brief 3/2020 (March 22, 2020)

Laut Berechnungen des Complexity Science Hub Vienna (CSH) könnten mit den derzeit verfügbaren Tests deutlich mehr Personen auf SARS-CoV-19 untersucht werden, wenn mehrere Proben zu einem Test zusammengeführt werden [1]. Die hier vorgestellte Methode gibt die optimale Pooling-Größe an. Bei 10.000 tatsächlich infizierten Personen in Österreich könnten mit 3.000 täglich verfügbaren Tests etwa 45.000 Menschen getestet werden. Liegt die Zahl der Infizierten bei 100.000, könnten etwa 15.000 Menschen täglich getestet werden. Pooling könnte somit dabei helfen, Engpässe bei den Tests deutlich zu entschärfen

R. Hanel, S. Thurner

Pooling corona tests could boost test efficiency by a factor of 10

CSH Policy Brief 3/2020 (EN) (March 22, 2020)

According to calculations by the Complexity Science Hub Vienna (CSH), significantly more people could be tested for SARS-CoV-19 with the tests currently available if several samples were combined into one test [1]. The method presented here indicates the optimal pooling size. With 10,000 actually infected persons in Austria, about 45,000 people could be tested, with 3,000 tests available daily. If the number of infected persons is 100,000, about 15,000 people could be tested daily. Pooling could thus help to significantly alleviate bottlenecks in testing.

S. Thurner, P. Klimek German

Coronavirus-Maßnahmen in Österreich eventuell zu gering, um Kapazitäts-limits von Spitalsbetten zu vermeiden

CSH Policy Brief 4/2020 (March 12, 2020)

Laut Berechnungen des Complexity Science Hub Vienna (CSH) könnte das Kapazitätslimit an Intensivbetten in österreichischen Spitälern in etwa 14 Tagen erreicht werden, das aller Betten Anfang April. Es sollten daher unbedingt Maßnahmen ergriffen werden, die stärker greifen als die implementierten Maßnahmen in Italien.

P. Klimek, S. Thurner, J. Sorger German

„Ich muss zur Ärztin!" Der fünfte Grund, das Haus zu verlassen

CSH Policy Brief 5/2020 (April 15, 2020)

Seit Mitte März herrschen in Österreich wegen der Corona-Pandemie strenge Ausgangsbeschränkungen. Ein ungewollter Effekt dieser Maßnahme wäre, wenn Menschen deshalb auf wichtige Arztbesuche verzichten oder diese zu lange verschieben. Um hier gezielt gegensteuern zu können, braucht es u.a. gut aufgeklärte ÄrztInnen.

P. Klimek, S. Thurner German

Wirksamkeitsstudie zur Reduzierung von COVID-19-Infektionen in Wien durch die frühzeitige Isolation von Verdachts-fällen im Zuge der Fahrten des Ärztefunkdienstes

CSH Studie 1/2020 (May 15, 2020)

Im Verlauf der Covid-19-Epidemie war der Ärztefunkdienst in Wien im Einsatz, um Verdachtsfälle direkt an den Wohnorten aufzusuchen und zu testen. Dadurch konnten weitere Ansteckungen durch einen Arzt- oder Spitalbesuch verhindert werden. Ziel dieser Studie ist es abzuschätzen, wie wirksam diese Tätigkeit des Ärztefunkdienstes beim Abflachen der Epidemiekurve in Wien tatsächlich war.

P. Klimek, S. Thurner German

Wirksamkeitsstudie: Abschätzung von Fall- und Todeszahlen in Abhängigkeit vom Zeitpunkt des Lockdowns in Österreich

CSH-Studie 2/2020 (May 27+June 2, 2020)

Am 16. 3. 2020 wurden österreichweite Maßnahmen zum Schutz der Bevölkerung in Zusammenhang mit der COVID-19-Pandemie eingeführt. Dieser Lockdown umfasste unter anderem die Schließung von Geschäften und Restaurants, Besuchsverbote sowie eine Reihe weiterer Maßnahmen. Im internationalen Vergleich hat Österreich auch relativ zu seiner Größe eine geringe Anzahl positiv getesteter Fälle (15.294 am 27. 4.) und an Corona-Toten (549 am 27. 4.) aufzuweisen. Diese Simulationsstudie versucht abzuschätzen, in welchem Ausmaß die am 16. 3. 2020 verkündeten Maßnahmen zu dieser Situation beigetragen haben. Insbesondere soll abgeschätzt werden, wie die Fallzahlen ausgesehen hätten, wäre der Lockdown eine bzw. zwei Wochen später verhängt worden, beziehungsweise hätte er in dieser Form gar nicht stattgefunden.

T. Reisch, C. Diem, W. Burton, S. Thurner German

Wie robust sind die österreichischen Lieferketten?

CSH Policy Brief 6/2020 (June 16, 2020)

Es ist von strategischer Bedeutung, die Zuliefernetzwerke der österreichischen Wirtschaft besser zu verstehen, um Schwachstellen identifizieren und die Wirtschaft systematisch resilienter und krisenbeständiger aufstellen zu können. Im Rahmen einer Umfrage wurden erstmals die Lieferkettenrisiken in der österreichischen Wirtschaft erhoben. Die Auswertung zeigt, dass ein Drittel der befragten Firmen mindestens einen Lieferanten hat, dessen Ausfall einen kompletten Stillstand des Betriebs bedeuten würde, nachdem die aktuellen Lagerbestände aufgebraucht sind. Für 55 Prozent dieser zentralen Lieferanten (bzw. 40 Prozent aller Zulieferer) gibt es keine Alternativen. Relativ hohe Lagerbestände puffern das Risiko, sodass es im Fall von Lieferausfällen nicht zu einem unmittelbaren flächendeckenden Produktionsausfall kommt.

P. Klimek German

Wie kritisch ist die Corona-Lage in Österreich? Und welche Maßnahmen brauchen wir? Versuch einer evidenz-basierten Antwort

CSH Policy Brief 7/2020 (Oct 12, 2020)

Eine unkontrollierte Ausbreitung von COVID-19 kann nach wie vor zu einer Überlastung des Gesundheitssystems führen, die zuerst in den Intensivstationen spürbar würde. Diesen Punkt würden wir bei etwa 4.700 bis 7.800 Neuinfektionen täglich erreichen. Ein zweiter Lockdown kann verhindert werden, wenn die Bevölkerung einfache Maßnahmen wie Hygiene und Abstandhalten mitträgt und – sollten die Fallzahlen weiter steigen – auf Risikoaktivitäten wie private Feiern so weit wie möglich verzichtet. Um das zu erreichen, sollten die Verantwortlichen auf Aufklärung, Transparenz und Empfehlungen setzen statt auf Drohungen und Verbote. Wir fordern außerdem, das Thema wieder stärker in der mittlerweile umfangreichen Evidenz zu verankern.

P. Klimek, S. Thurner German

Vom exponentiellen Anstieg der Infektions-zahlen und der Wichtigkeit genauer Daten

CSH Policy Brief 8/2020 (Nov 12, 2020)

Der rasante Anstieg bei den Corona-Fallzahlen der vergangenen Wochen in Österreich hat deutlich gemacht, dass sich die Virusdynamik zunehmend in unregelmäßigen Schüben beschleunigt, die kurzfristig einem schneller-als-exponentiellen Wachstum gleichkommen. Der vorliegende Policy Brief erklärt die Problematik der unterschiedlichen Wachstumskurven, erklärt damit, warum es ein viel detaillierteres Verständnis des Infektionsgeschehens braucht, und dass eine massiv verbesserte Datenlage unabdingbar ist, wenn wir das Instrument der Kurzzeit-Prognose nicht verlieren wollen.

J. Lasser, L. Richter, D. Schmid, J. Sorger, S. Thurner, P. Klimek German

Effektivität von Präven-tionsmaßnahmen für SARS-CoV2 und seine transmissibleren Varianten für eine nachhaltige Öffnung der Schulen

CSH Policy Brief 1/2021 (together with AGES) (Jan 20, 2021)

Um monatelanges Verharren in Lockdowns zu vermeiden, benötigen wir verbesserte Präventionskonzepte für Orte, an denen es weiterhin zu Kontakten kommen soll. Besondere gesellschaftliche und psychosoziale Bedeutung kommt dabei der nachhaltigen Öffnung von Schulen zu. Aufbauend auf AGES-Cluster-Daten im Schulsetting entwickeln wir ein agenten-basiertes Modell zur Ausbreitung von SARS-CoV2 in Österreichs Schulen. Damit kann die Wirksamkeit von Kombinationen von Präventionsmaßnahmen abgeschätzt werden: Lüften, Maskentragen während des Unterrichts, gestaffelter Unterricht sowie Screenings mittels Antigen-Schnelltests.

P. Klimek, G. Heiler German

Von Lockdown zu Lockdown: Über die Entwicklung der Mobilitäts-reduktion in Österreichs Bundesländern

CSH Policy Brief 2/2021 (Jan 25, 2021)

Eine Analyse von Bewegungsdaten legt nahe, dass sich der Effekt von Lockdowns auf die Mobilität abnutzt. Während Lockdown 1 (März 2020) betrug die Mobilität 30 Prozent verglichen mit dem gleichen Zeitraum im Jahr 2019. Im zweiten Lockdown (November 2020) betrug sie 40 Prozent (von einem vergleichsweise geringeren Niveau von ca. 80 Prozent im Sommer kommend). Im gegenwärtigen dritten Lockdown ist kein deutlicher Einbruch feststellbar. Momentan stehen wir bei ca. 70 Prozent im Vergleich zum Jänner 2020. Zu beobachten ist zudem ein West-Ost-Gefälle mit der stärksten Mobilitätsreduktion im Osten, vor allem in Wien.

P. Klimek, S. Thurner, G. Heiler German

Hin zu einer regionali-sierten Niedriginzidenz-Strategie für kommende Covid-19-Infektionswellen

CSH Policy Brief 3/2021 (Apr 19, 2021)

Handlungsanweisung zu einer Niedriginzidenz-Strategie (...): Wird der Grenzwert für Ausreisetests von derzeit 400 (7-Tage-Inzidenz) auf 100 gesenkt, kann man mit bundesweiten 7-Tage-Inzidenzen von 50 rechnen, bei einem Grenzwert von 25 mit einer Inzidenz von 10. Eine 7-Tage-Inzidenz von 50 ist im österreichischen Gesundheitssystem nachhaltig managebar. Das bedeutet, dass bei Öffnungsschritten das Konzept der Ausreisetests keinesfalls aufgegeben werden sollte, sondern im Gegenteil der Grenzwertmit fallenden Fallzahlen schrittweise auf 25 gesenkt wird. Diese Präventionsstrategieführt auch mittelfristig zu einer sehr niedrigen Wahrscheinlichkeit, dass eine Region zur Hochinzidenzregion wird, und ist ein zentraler Baustein zur pandemischen Kontrolle.

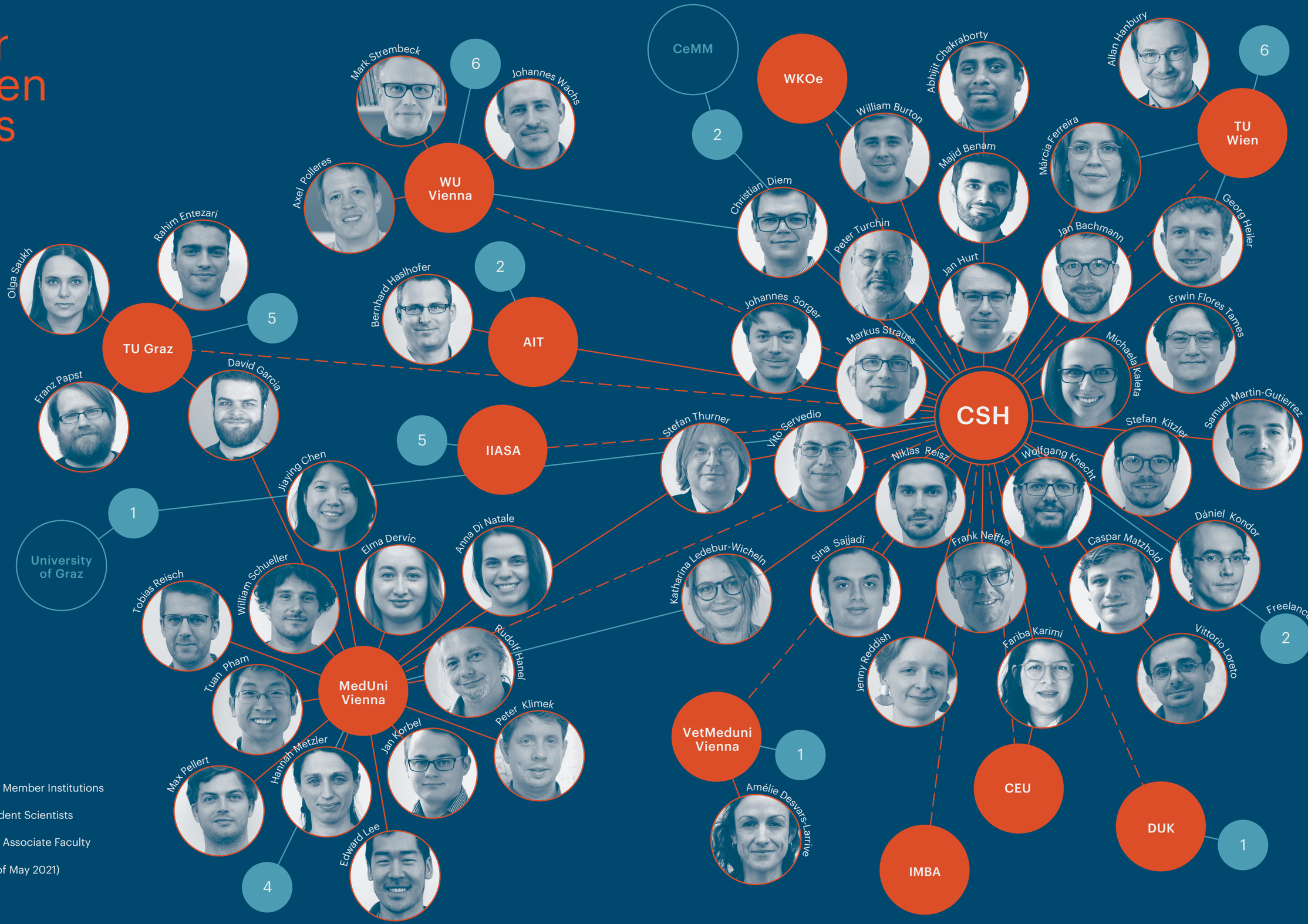
All About the Hub

The Complexity Science Hub Vienna officially started operations in May 2016. The objective of the newly established institution was to bundle, coordinate, and strengthen existing initiatives related to complexity science, systems analysis, and Big Data science in and around Vienna to achieve international visibility and relevance.

Turn the pages for an extended Tour de Hub: Meet our scientists, members, and faculties. See how we organize “Hub Life” and find the “Hub Live” events: the workshops, talks, visitors, and winter program of the first five years as well as our various outreach activities.

With everything we do we strive to leave behind the usual (university) concepts of “group thinking”, and to provide an environment that allows true interdisciplinarity to thrive. We strongly believe that only when our people with all their different scientific (and cultural) backgrounds, their ideas and opinions, regularly interact, will the CSH be able to leave the beaten tracks and develop something entirely new.

Our Scientists



CSH Member Institutions
Resident Scientists
CSH Associate Faculty

(As of May 2021)

Timeline Resident Scientists Management

June 16, 2015
CSH officially founded

May 23, 2016
CSH starts operations

Nov 2016
First CSH Science Advisory Board Meeting

Jan 2017
Start building CSH External Faculty

May 2017
First CSH Associate Faculty Meeting

Feb 2017
First *Art at the Hub* Vernissage and Book Presentation *Visions for Complexity*

May 2018
First CSH External Faculty Meeting & Public Conference

March 2019
First CSH Winter School

Charlotte Hofer ›
Stefan Kitzler ›
Daniel Kondor ›
Samuel Martin-Gutierrez ›
Frank Neffke ›
Sina Sajjadi ›
Jan Bachmann
Fariba Karimi
Katharina Ledebur
Edward Lee
Majid Benam
Emine Güldüroglu
Bernhard Haslhofer
Jan Hurt
Michaela Kaleta
Peter Turchin
William Burton
Johannes Wachs
Stephanie Bourke-Altmann
Abhijit Chakraborty
Hannah Metzler
Andrew Ringsmuth
Jana Lasser
Amélie Desvars-Larrive
Márcia Ferreira
Erwin Flores Tames
Jenny Reddish
William Schueller
Jiaying Chen
Christian Diem
Wolfgang Knecht
Caspar Matzhold
Tobias Reisch
Franz Papst
Elma Dervic
Anna Di Natale
Georg Heiler
Rahim Entezari
Huda Takriti
Ancsa Hannak
Simon Schweighofer
Niklas Reisz
Carlos Molinero
Markus Strauss
Max Pellert
Allan Hanbury
Sebastian Poledna
Sarah Etter
Nina (Nils) Haug
Johannes Sorger
Verena Ahne
David Garcia
Jan Korbel
Michael Miess
Tuan Pham
Olga Saukh
Laura Stöger
Vittorio Loreto
Michaela Zach
Ruggiero Lo-Sardo
Leonardo Zavojanni
Leonhard Horstmeyer
Javier Fernández
Axel Polleres
Vito Servedio
Mark Strembeck
Philipp Marxgut
Bernat Corominas-Murtra
Rudolf Hanel
Peter Klimek
Stefan Thurner

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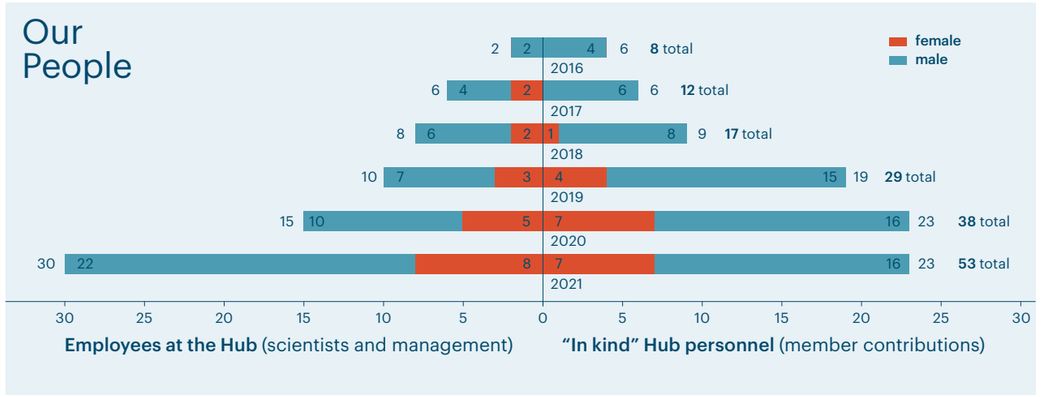
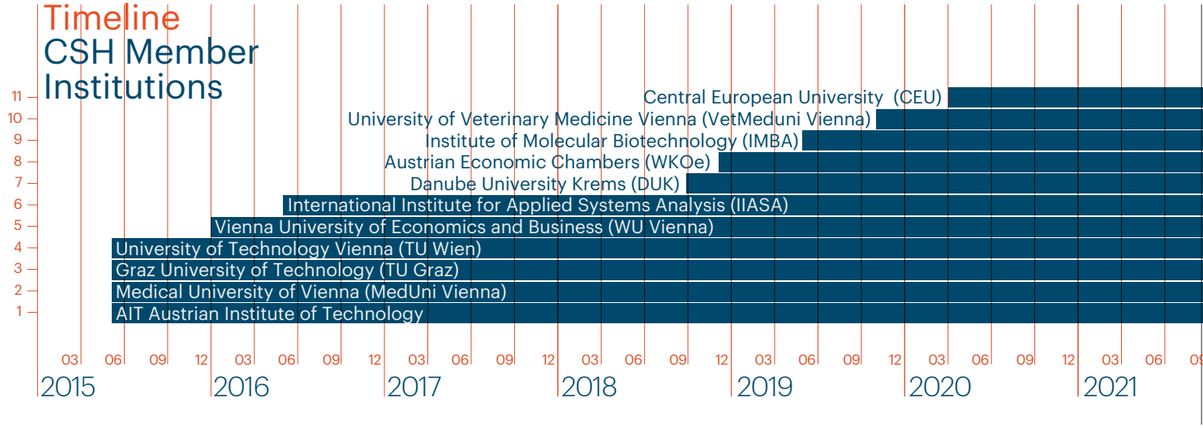
2015 2016 2017 2018 2019 2020 2021





The CSH Structure

The Hub is one of the few Austrian institutions that not only employs, but also produces first-class digitization experts. These experts are—and will be—able to systematically generate meaning and value from Big Data.

In the first five months of 2021 alone, we signed up nine new resident scientists and established three new research topics at the Hub. As of May 2021, the scientific Hub team consisted of more than 50 people.

But we intend to grow further. The plan for the next five years: We want to become one hundred first-class digitization experts the country—and the world—so urgently needs.

CSH RESIDENT SCIENTISTS

Our resident scientists are **(1)** researchers employed by one of our member institutions and seconded to the Hub, and **(2)** scientists directly employed by the Hub.

Members of the CSH Faculty are Senior Researchers that have to be approved by the Science Advisory Board.

As of May 2021, the Hub had 49 resident scientists.

CSH ASSOCIATE FACULTY

Members of the CSH Associate Faculty are our links to CSH Member Institutions and other cooperation partners interested in complexity science.

As of May 2021, 35 scientists from ten Austrian universities and research institutions were appointed as CSH Associate Faculty (two are freelancers):

CSH EXTERNAL FACULTY

The CSH External Faculty consists of highly recognized researchers who are willing to strengthen the objectives of the Hub, regularly share a certain amount of time with us, and organize workshops and seminars at the Hub. Their appointments have to be approved by the Science Advisory Board.

CSH JUNIOR FELLOWS

Every now and then, we spot young scientists with whom we want to stay in contact. We invite them to become CSH Junior Fellows, to regularly spend time at the Hub to work on scientific projects and interact with fellow researchers to the benefit of both sides.

As of May 2021, we have had four Junior Fellows.

OUR MEMBER INSTITUTIONS

The Hub grew from four founding members to eleven members in May 2021.

These partners **(1)** contribute member fees and **(2)** provide us in kind with senior scientists (tenure track positions, PostDocs, PhDs) who share workspace and cooperate scientifically at the Hub, guaranteeing a critical mass of people who regularly meet and interact in one place.

The various backgrounds of these scientists reflect the topical interests of the participating institutions in complexity research.

CSH Member Institutions

AIT Austrian Institute of Technology

CEU Central European University

Danube University Krems – The University for Continuing Education

IIASA International Institute for Applied Systems Analysis www.iiasa.ac.at

IMBA Institute of Molecular Biotechnology of the Austrian Academy of Sciences

Medical University of Vienna

TU Graz Graz University of Technology

TU Wien Technische Universität Wien Vienna | Austria

vetmeduni vienna

WKO

WU Wirtschaftsuniversität Wien Vienna University of Economics and Business

Alex Arenas
W. Brian Arthur
Stefano Battiston
Michael Batty
Luis Bettencourt
Tamás Biró
Stefan Bornholdt
Miguel A. Centeno
Siew Ann Cheong
Álvaro Corral
Raissa M. D'Souza
Simon DeDeo
Tiziana Di Matteo
J. Doyne Farmer
Mirta Galesic
Sergey Gavrilets
Aniko Hannak
Shlomo Havlin
Dirk Helbing
John Hogan
Carlo Jäger
Henrik Jensen
Kimmo Kaski
Stuart Kauffman
János Kertész
Imre Kondor
David Krakauer
Christian Kühn
Renaud Lambiotte
Stephen J. Lansing
Vito Latora
Manfred Laubichler
Rosario Mantegna
Yamir Moreno
Matjas Perc
Ruth Pfeiffer
Luciano Pietronero
Sonja Prohaska
Andrea Rapisarda
Diego Rybski
Maxi San Miguel
Gerhard Schmitt
Frank Schweitzer
M. Ángeles Serrano
Roberta Sinatra
Peter M. A. Sloot
Eric Smith
Ricard Solé
Didier Sornette
Markus Strohmaier
Michael Szell
Bosiljka Tadic
Francesca Tria
Constantino Tsallis
Sander Van Der Leeuw
Alessandro Vespignani
Angelo Vulpiani
Claudia Wagner
Geoffrey B. West
Karoline Wiesner
David Wolpert

CSH External Faculty

Main and further affiliations

Aalto University School of Science
Alan Turing Institute
Alma Mater Europaea ECM
Arizona State University
Bar-Illan University
Beijing Normal University
Brazilian Center for Research in Physics
Carnegie Mellon University
Catalan Inst. for Research&Advanced Studies
Central European University
China Medical University Hospital
École Normale Supérieure de Lyon
ETH Zurich
GESIS – Leibniz Institute for the Social Sciences
Global Climate Forum e. V.
Imperial College London
Institute for Systems Biology
Institute of Innovative Research
ISI Foundation
IT University of Copenhagen
ITMO University
Jožef Stefan Institute
King's College London
Leipzig University
London Mathematical Laboratory
Massachusetts Institute of Technology
Nanyang Technological University
National Cancer Institute, Maryland
Northeastern University
Palo Alto Research Center
Parmenides Foundation
Potsdam Inst. for Climate Impact Research
Princeton University
Queen Mary University of London
Ronin Institute
Royal Swedish Academy of Sciences
RWTH Aachen University
Santa Fe Institute
Sapienza University of Rome
Singapore-ETH Centre
Stockholm Resilience Centre
Technical University of Munich
Tokyo Institute of Technology
TU Delft
Universidad Rovira i Virgili
Università degli Studi di Palermo
Universitat Pompeu Fabra
University College London
University of Amsterdam
University of Barcelona
University of Bremen
University of Bristol
University of California, Davis
University of Catania
University of Chicago
University of Geneva
University of Maribor
University of Oxford
University of Potsdam
University of Tennessee
University of the Balearic Islands
University of Zaragoza
University of Zurich
Wigner Research Centre for Physics

Affiliations CSH External Faculty

- Aalto University School of Science
- Alan Turing Institute
- Alma Mater Europaea ECM
- Arizona State University
- Bar-Illan University
- Beijing Normal University
- Brazilian Center for Research in Physics
- Carnegie Mellon University
- Catalan Inst. for Research & Advanced Studies
- Central European University
- China Medical University Hospital
- École Normale Supérieure de Lyon
- ETH Zurich
- GESIS–Leibniz Institute for the Social Sciences
- Global Climate Forum e. V.
- Imperial College London
- Institute for Systems Biology
- Institute of Innovative Research
- ISI Foundation
- IT University of Copenhagen
- ITMO University
- Jožef Stefan Institute
- King's College London
- Leipzig University
- London Mathematical Laboratory
- Massachusetts Institute of Technology
- Nanyang Technological University
- National Cancer Institute, Maryland
- Northeastern University
- Palo Alto Research Center
- Parmenides Foundation
- Potsdam Inst. for Climate Impact Research
- Princeton University
- Queen Mary University of London
- Ronin Institute
- Royal Swedish Academy of Sciences
- RWTH Aachen University
- Santa Fe Institute
- Sapienza University of Rome
- Singapore-ETH Centre
- Stockholm Resilience Centre
- Technical University of Munich
- Tokyo Institute of Technology
- TU Delft
- Universidad Rovira i Virgili
- Università degli Studi di Palermo
- Universitat Pompeu Fabra
- University College London
- University of Amsterdam
- University of Barcelona
- University of Bremen
- University of Bristol
- University of California, Davis
- University of Catania
- University of Chicago
- University of Geneva
- University of Maribor
- University of Oxford
- University of Potsdam
- University of Tennessee
- University of the Balearic Islands
- University of Zaragoza
- University of Zurich
- Wigner Research Centre for Physics

Locations

- Aachen, Germany
- Amsterdam, Netherlands
- Barcelona, Spain
- Beijing, China
- Berlin, Germany
- Bethesda, USA
- Boston, USA
- Bremen, Germany
- Bristol, GB
- Budapest, Hungary
- Cambridge MA, USA
- Catania, Italy
- Chicago, USA
- Cologne, Germany
- Copenhagen, Denmark
- Davis, USA
- Delft, Netherlands
- Dresden, Germany
- Espoo, Finland
- Geneva, Switzerland
- Graz, Austria
- Knoxville, USA
- Krems, Austria
- Laxenburg, Austria
- Leipzig, Germany
- Leuven, Belgium
- Ljubljana, Slovenia
- London, GB
- Lyon, France
- Maribor, Slovenia
- Montclair, USA
- Munich, Germany
- Namur, Belgium
- Oxford, GB
- Palermo, Italy
- Palma de Mallorca, Spain
- Palo Alto, USA
- Paris, France
- Pittsburgh, USA
- Potsdam, Germany
- Princeton, USA
- Ramat Gan, Israel
- Rio de Janeiro, Brazil
- Rome, Italy
- Saint Petersburg, Russia
- Santa Fe, USA
- Seattle, USA
- Singapore, Singapore
- Stanford, USA
- Stockholm, Sweden
- Storrs, USA
- Taichung, Taiwan
- Tarragona, Spain
- Tempe, USA
- Tokyo, Japan
- Torino, Italy
- Ubud, Indonesia
- Vienna, Austria
- Zaragoza, Spain
- Zurich, Switzerland

Affiliations CSH Associate Faculty & CSH Resident Scientists

- AIT Austrian Institute of Technology
- Capital Fund Management
- Catholic University Leuven
- CeMM Research Center for Molecular Medicine
- Danube University Krems
- TU Graz
- Institut d'Études avancées de Paris
- Institute for Advanced Study
- Inst. for Globally Distributed Open Research and Education
- International Institute for Applied Systems Analysis (IIASA)
- London School of Economics
- Max Perutz Labs
- Medical University of Vienna
- National Institute for Nuclear Physics+Universita di Catania
- Sony-CSL Paris
- Stanford University
- Stockholm University
- Technische Universität Dresden
- TU Wien
- University of Connecticut
- University of Namur
- University of Natural Resources and Applied Life Sciences
- University of Veterinary Medicine Vienna
- University of Vienna
- Vienna University of Economics and Business
- Wegener Center for Climate and Global Change
- Wittgenstein Centre for Demography and Global Human Capital

Net working

Connected with 23 countries, 60 cities and towns, 91 scientific institutions —the Hub is a true hub in a worldwide scientific network. These strong ties allow for an efficient flow of ideas and a stimulating exchange of scientists.

- CSH External Faculty
- Location of institutions
- CSH Associate Faculty & CSH Resident Scientists

* The CSH network of affiliations is constantly evolving. This is a snapshot from May 2021.

Hub Life & Hub Live

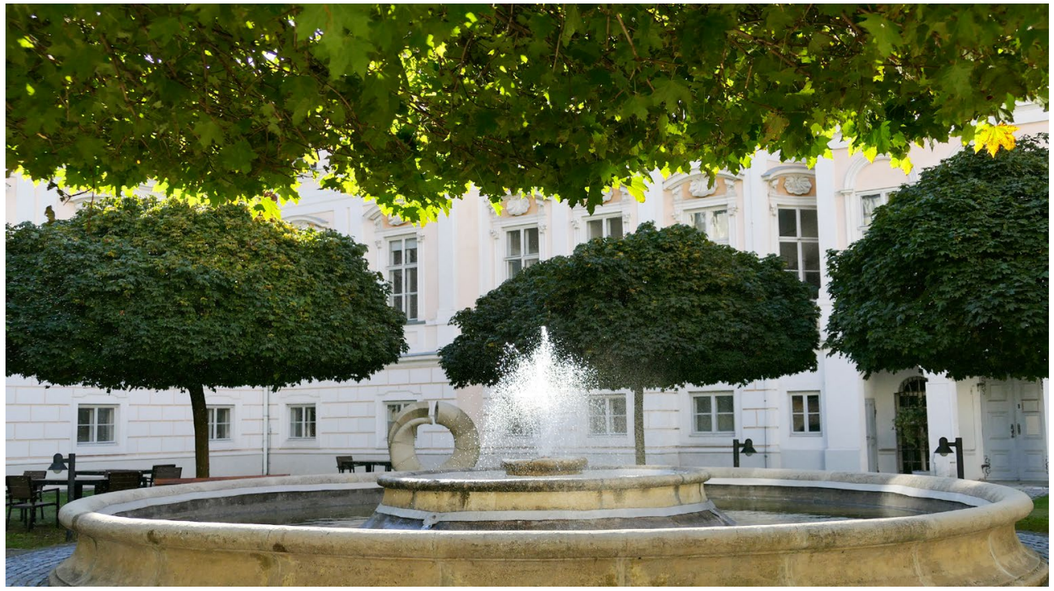
Apart from its great people: What makes working at the Hub so special?

The Palace

Our workspace is located in a historic building in downtown Vienna: the Palais Strozzi. These 320-year-old walls surely contribute a lot to the Hub's atmosphere. Whoever pays us a visit—or starts working with us—is impressed by the baroness's stairways, the wide, long aisles, laid with shiny old stone tiles, or the high, spacious rooms, often decorated with "Art at the Hub"...

On top of the indoor qualities, we also enjoy the space around the building. Entering the Palais from noisy Josefstädter Strasse, you will find yourself in a large inner courtyard with baroque trees, bird songs, a lovely fountain (and an automatic lawn mower that mercilessly decapitates every little flower that dares to grow). Together with a hedged garden in the rear of the building, the green spaces around Palais Strozzi offer a garden view from almost all our rooms. Moreover, we have the possibility for table tennis, luncheons in the sun, summer parties, or after-work chats stretched out in a beach chair...

Admittedly, the monument protection of the Palais has its downsides, too. We don't have air conditioning, which can be really hard when the summers become (increasingly) hot; and we have to obey various rules when it comes to nails in the walls or food in the halls... But we can take that.



The Social Life

One goal we are working on every day is to provide an inspiring environment for our researchers. We want people to meet and interact, to forget about the usual thinking in “groups,” “research fields,” or “disciplines,” but to embrace the opportunity to create something truly inspiring and innovative by mixing, rearranging, and setting off to new complex and interdisciplinary shores.

One opportunity to regularly meet’n’greet is our daily teatime—at least in non-corona times. Summoned by a bell at 4 o’clock, we gather in the Salon (if the weather is nice, also outside) for tea, coffee, and some snacks to chat a little, to encounter other students, new scientists, old friends, or Hub visitors from all around the world.

Our teatime dream is that these encounters might lead every now and then to solving unsolvable problems, or hatching truly new ideas—through interaction and intellectual exchange.

THE BEER GROUP

Whoever is new at the Hub and wishes so, will quickly be added to the infamous Beer Group. First on WhatsApp, now on Signal, the Beer Group has long left its initial purpose of making appointments for afterwork beer rounds

(or sometimes sports) easier. The Beer Group has evolved into kind of a virtual blackboard for Hub people, a place for questions, suggestions, or any other form of exchange.

Looking for a bicycle companion for the weekend? A new dentist? A (rare) plant lover who will reliably water the pots in your office while you are abroad? Stuck with a specific coding question, eager to share the excitement about a TV show, or wondering where to find (insert any word you please)? Whatever the problem is: The Beer Group will surely produce an answer. Or several dozen answers. (It can be noisy at times. But always fun noise!)

HUB LIFE IN CORONA TIMES

Well, we can keep this chapter short: there is none. Only a few people sneak around the place, rather trying to avoid personal encounters than looking for some... We dearly miss our visitors, live talks, group work, chat rounds, the teatime, of course... May live Hub life return sooner better than later!

Crazy, Crazier, Craziest Works hop!

"And what is your craziest idea?" The Hub wanted to know—and called its scientists (and other staff) to a two-day workshop outside of Vienna.

Researchers, probably like most humans, from time to time have ideas that seem too crazy to be pursued and therefore stay carefully hidden. But what if such an idea was a treasure, worth further investigation? This thought drove Vito Servedio, data scientist and culinary magician of the Hub, crazy. We should dare to let our hidden ideas out, Vito thought—and initiated the first crazy workshop in early summer 2020, when corona cases were very low in Austria.

After crazily busy weeks within and after the first lockdown, we Hub people were happy to travel to beautiful Helenental in Lower Austria, to put our heads together (not literally of course!), and eventually choose the best of all crazy ideas.

The workshop started with some crazy (and admittedly some not-so-crazy) presentations. Anna di Natale wondered if blackouts lead to higher birth rates. William Schueller asked if language could be seen as an efficient cognitive cheating system. Rudi Hanel spun ideas around "cognitomics—notions in motion"...

In the evening, after a frugal meal, brains were challenged with a hellish pub quiz. Not even the more-than-smart CSH crowd was able to solve these questions, put together by Stephanie Bourke-Altmann and Márcia Ferreira. Our physical condition was tested with swimming, cheerful ball games, and an extremely exhausting 25-minute walk around the hotel.

But the highlight of the jolly excursion was the crazy battle in the end. Andrew Ringsmuth won it, although nobody really understood what he was up to (he argued that the first economic system may have appeared around one billion years ago, when photosynthetic microorganisms began to cooperate, or something the like). Yet, his garden presentation was so convincing that he went home with a precious prize.

It can surely be said that the first CSH retreat and first ever Crazy Workshop & Battle was a great success. After months of lockdown with hardly any physical interaction at work or socially, we returned to Vienna inspired, motivated, and crazily refreshed.

CSH Workshop Series

Workshops are our innovation engines. They are designed to provide free space for discussions, musing, collaborate thinking, and—maybe & hopefully—breaking new scientific ground.

In the framework of the CSH Workshop Series, scientists affiliated with the Hub are given the opportunity to invite the world's leading experts in a specific field to explore or clarify the potential of emerging scientific questions or new research directions. An ideal-typical workshop (in non-COVID-19 times) involves about 10 to 20 scientists who spend two to three days together at the Hub.

Find out what scientists discussed in the past five years.

Presentations marked with this icon were recorded and can be seen on our YouTube channel.

May 27, 2016

Dynamic Networks, Autocatalytic Sets, and Evolutionary Dynamics

Organizer:
Stefan Thurner (CSH)

This workshop was intended as an informal brainstorming event for identifying possibilities for future Austro-Hungaro-American collaborations on evolutionary systems, self-maintaining and autocatalytic sets, and evolutionary complex systems.
Scientists in the field of evolution and its dynamics discussed the issue of autocatalytic sets and their applications, ranging from pure mathematics to the community structure of the microbiome.

Oct 10–11, 2016

Future Directions in Medical Data Science

Organizer:
Peter Klimek (Medical University of Vienna & CSH)

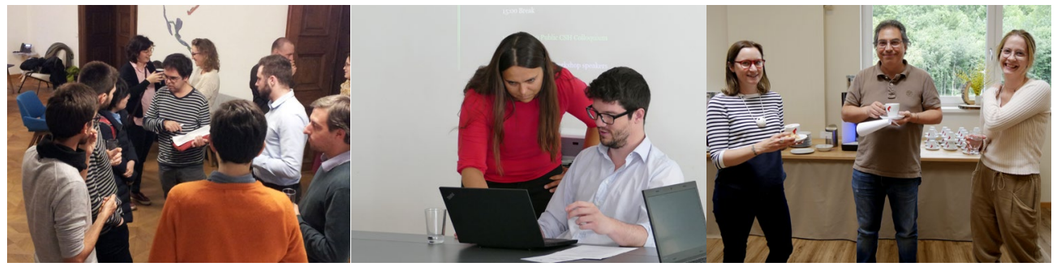
Most chronic disorders are caused by multiple genetic processes that act in concert with environmental factors. Recent advances in handling and analyzing large datasets on such disease-causing mechanisms, their interactions, and their associated phenotypes enable a novel, quantitative, and data-driven approach to understanding human disease.
The workshop made clear that a new approach to medicine is currently emerging: It makes use of methods from complexity science, such as networks and their generalizations, in order to integrate data from healthcare and several omics from biology. The new approaches have the potential to revolutionize healthcare and medicine by providing a data-driven and comprehensive understanding of human disease, particularly in terms of personalized health risk assessment, individualized disease prevention, and the avoidance of adverse drug effects.

Nov 10–12, 2016

Approaches to the Evolution of Complex Systems

Organizers:
Stefan Thurner (CSH)
Johannes Jäger (Konrad Lorenz Institute KLI, Klosterneuburg)
Manfred Laubichler (Arizona State University & CSH External Faculty)
Ulf Diekmann (International Institute for Applied Systems Analysis IIASA & CSH Associate Faculty)

Evolutionary processes pose fundamental challenges to a quantitative predictive understanding. One of the main reasons for this lack of predictability is the fact that the configuration space of evolving



complex systems cannot be pre-stated. Dimensionality and boundary conditions change with every innovation. These systems incessantly explore what Stuart Kauffman has termed the "adjacent possible."
As humanity is facing numerous complex challenges, the need to rigorously understand evolutionary systems is bigger than ever before. The aim of this interdisciplinary workshop was to creatively explore new routes to study the evolution of complex systems.
An increased understanding of complex evolutionary dynamics will have wide implications for the analysis and management of health, eco-systems, financial markets, societal change, and innovation in the economy.

Feb 2–3 & Feb 23, 2017

Possibilities to Introduce Payment and Value Systems for Emerging Economies in Refugee Societies

Organizers:
Stefan Thurner (CSH)
Harald Gründl (Institute of Design Research Vienna)

This workshop aimed at fathoming the possibility to create an intelligent, app-based payment system (electronic currency) for people living in refugee camps. Such a system should be designed to not only stimulate the economy in the camps, but also feed information back to participants to see their economy emerging and visualize possibilities to create new activities. Options on how to create a prototype app were discussed. To start the workshop, a refugee camp in Vienna and several other initiatives that kick-started an economy were visited. Feedback from a workshop with more than 100 refugees is included for the next steps and the design and functionalities of the app.

May 8–9, 2017

Re-inventing Society in the Digital Age

Organizers:
Dirk Helbing (ETH Zurich & CSH External Faculty)
Stefan Thurner (CSH)

The digital revolution will leave no one untouched. Digital technologies will fundamentally change the area of services and product portfolios. Entire business models and economic sectors, institutions and even our living together as a society will change—completely new ecosystems will emerge. Even if Industry 4.0 may initially come to mind when one considers the concept of digital revolution, this does not go far enough, and the end of the development is still far from being reached. What it will take is Education 4.0, Mobility 4.0, Health Systems 4.0, Science 4.0, Innovation 4.0, Finance 4.0, Sustainability 4.0, Governments 4.0—in short, an overall, comprehensive Society 4.0. But how exactly might this digital future look like? How do we want our future society to be, and how will we get there? The workshop aimed to shed light on the impact of digital technology on different areas of our daily lives and attempted to sketch out the first outlines of a Society 4.0.

Sept 26, 2017

Data-Informed Urban Planning

Organizer:
Reinhard König (Austrian Institute for Technology AIT & CSH Associate Faculty)

New technologies influence how we use and transform our cities. In this context, the main challenge for ensuring smart and livable future cities is to use the flood of data for urban services and for assisting urban planning and design processes.
In the workshop, methods for collecting and analyzing datasets from urban environments for developing predictive models and for assisting urban design processes for a new kind of digital master plan were discussed. The workshop aimed to connect experts with different backgrounds to stimulate new collaborations and innovative future research directions.

Oct 2–3, 2017

Evolution of Social Complexity

Organizer:
Peter Turchin (University of Connecticut & CSH External Faculty)

Over the past 10,000 years, human societies evolved from "simple"—small egalitarian groups, integrated by face-to-face interactions—to "complex"—huge anonymous societies of millions, characterized by great differentials in wealth and power, extensive division of labor, elaborate governance structures, and sophisticated information systems. Social complexity, however, is a characteristic that has proven difficult to conceptualize and quantify. Many researchers argue that there is no single dimension along which social complexity can be measured; there must be multiple dimensions or variable manifestations of complexity. Another common view is that different societies have unique histories and cannot be meaningfully compared in this way.
At this workshop, researchers from a variety of disciplinary backgrounds discussed: Can we measure social complexity? How many dimensions does it have? Can results from a recent analysis of 400 societies in Seshat: Global History Databank throw light on these questions? Assuming we can quantify it: What were the evolutionary forces that explain the dramatic increase in social complexity over the past 10,000 years? And, finally, is there a downside to complexity—are overly complex societies unstable and vulnerable to collapse?

Oct 19–20, 2017

Theory of Sample Space Reducing and Expanding Processes

Organizers:
Stefan Thurner (CSH)
Henrik Jensen (Imperial College London & CSH External Faculty)

Systems and processes with sample spaces or phase spaces that are not constant, but change over time, seem to be at the heart of many complex systems. Yet the mathematical structures behind these processes are practically unexplored.
The workshop aimed to clarify where we stand with the current understanding, if the current approaches that have been explored by various groups can be unified, and where to go in terms of possibilities of further fundamental understanding of these processes and their statistics.

Oct 26, 2017

WeCoS: Understanding the Web as a Complex System—Complexity Science Meets Web Science

Organizers:
Axel Polleres (Vienna University of Economics & Business & CSH)
David Garcia (CSH)
Vito DP Servedio (CSH)

The WeCoS workshop aimed at bringing together researchers from the Semantic Web, Web Science, and Complexity Science for a truly interdisciplinary workshop about revisiting the question of understanding the Web from different angles, deliberately looking outside of the core Semantic Web community for new and complementary approaches from empirical, theoretical, and social sciences to tackle the question of understanding the meaning of phenomena on the Web as a complex system.

Oct 31, 2017 CSH–CEU Workshop

Budapest Meets Vienna

Organizers:
János Kertész (Central European University & CSH External Faculty)
Stefan Thurner (CSH)

At this workshop, researchers from the Complexity Science Hub Vienna and the Center for Network Science at Central European University Budapest (CEU) discuss various areas for cooperation.

"For our workshop, we envisage a mindset that does not rest in the past, a mindset that does not look for greedy increments, but rather one that is prone to leaps and to visions and to the big problems or challenges ahead of us. The idea of a workshop at the Hub is not for individuals to talk only about their work, get inspiration only for their work and get back to their work, but rather for the participants to come together at eye level, discuss perspectives that are beyond themselves and to join forces to tackle them. For this reason, we focus on discussions rather than talks."

Stefan Thurner, CSH President

Nov 2–4, 2017

Adaptive Co-Evolving Networks and Catastrophes

Organizers:
Stefan Thurner (CSH)
Leonhard Horstmeyer (Medical University of Vienna & CSH)
Christian Kühn (Technical University of Munich & CSH External Faculty)

Adaptive co-evolving dynamic networks play a key role in ecological, epidemiological, social or financial systems. To understand the efficiency, resilience, and systemic risks of such networks one needs a much deeper mathematical understanding of their critical behavior than is currently available. What remains largely unknown about these systems is their phase structure, their critical transitions, if they can be classified into universality classes and whether it is possible to derive network-based early-warning signals.
In particular, the workshop participants discussed to what extent the network topology captures information about the critical transition and whether this allows the limits of predicting regime shifts and catastrophic events to be explored.

Jan 25–27, 2018

Information Theory and Non-Equilibrium Thermodynamics Beyond the Shannon-Gibbs Framework

Organizers:
Bernat Corominas-Murtra (Medical University of Vienna & CSH Associate Faculty)
Rudolf Hanel (Medical University of Vienna & CSH Associate Faculty)

Understanding the connection between information and thermodynamics is a keystone on the way towards grasping the emergence of complexity. In systems without path-dependence or in equilibrium, these relations are fairly well understood: On the one hand, Shannon entropy can be justified either from information-theoretic grounds or from an equilibrium thermodynamic approach. On the other hand, Landauer's principle gives us a fundamental relation between information erasure and thermodynamic cost.
Yet, the solid ground those concepts are built on dissolves completely when going to systems with path-dependence or non-equilibrium systems. While recent approaches provided a conceptual basis for generalized forms of information theory, the connection between these theoretical approaches to (non-equilibrium) thermodynamic concepts is far from being understood. At the same time, new developments generalizing Landauer's principle to non-equilibrium scenarios become available, but many important pieces in this puzzle still are far from being firmly grounded.
This workshop intended to explore potentially promising future research paths aiming at a comprehensive integration of the abovementioned disciplines. In addition, it discussed the possible application of these theoretical approaches, from biological to technological systems.

Feb 1–2, 2018

Social Informatics: En Route Towards Asimov's Psychohistory?

Organizer:
Kimmo Kaski (Aalto University & CSH External Faculty)

Social Informatics or Data-driven Social Sciences represents a new transdisciplinary field of research that focuses on studying societal-scale social phenomena in interplay with today's increasingly socially centric and multi-channeled information communication technology (ICT)-based platforms. The goal of Social Informatics is, on one hand, to understand the anatomy, i.e., the structure, dynamics, and functions, of human social connectomes or networks. On the other hand, it is to create a better understanding of socially-centric platforms not just as a technology, but also as a set of social phenomena, as well as of the roles of information technology in social and organizational change, the uses of information technologies in social contexts, and the ways that the social organization of information technologies is influenced by social forces and social practices.
Such understanding is crucial in applying information technology in the study of social phenomena, in applying social concepts in the design of information systems, in applying methods from the social sciences in the study of social computing and information systems, in applying computational analytics and modelling to facilitate the study of social systems and human social dynamics, and in designing information and communication technologies that consider social context. Social Informatics relies on the analysis of large-scale datasets on human interaction and social dynamics and their computational modelling, thus being interdisciplinary and combining methodologies of Social Sciences, Management Sciences, Computer Science, Informatics, and Physics.

May 7, 2018
CSH–ETH Preparatory Workshop

City Climate Olympics

Organizer:
Dirk Helbing (ETH Zurich & CSH External Faculty)

The Olympic Games are held every two years and attract hundreds of millions of viewers worldwide, just to see how people compete in different sports. Why not adopt this idea in other areas, such as countering climate change and fostering sustainability?
Cities and social communities can be important agents of global change. In

what ways can a participatory approach contribute to reaching the United Nation's Sustainability Goals, as laid out in the Agenda 2030, the Paris Climate Accords, and elsewhere?
At this workshop, the participants brainstormed on new ways to organize the Global City Climate Olympics, an event for cities and regions around the world to regularly compete for the best environmental-friendly, energy-efficient, resource-saving and crisis-proof solutions.

June 8–9, 2018

Improving Resilience in Complex Systems

Organizers:
Frank Schweitzer (ETH Zurich & CSH External Faculty)
Stefan Thurner (CSH)

Resilience denotes the capacity of a system to withstand shocks and the ability to recover from them. But how should it be quantified and measured for complex systems with a large number of degrees of freedom?
Existing concepts of resilience, e.g., in engineering or population biology, do not lead us very far when it comes to highly volatile social organizations. To what extent can disciplinary approaches on robustness, stability, and adaptation be applied in a different context? And how should Big Data analytics be utilized to better estimate the resilience of complex systems? To discuss such questions requires experts with the ability to cross scientific boundaries.

June 11–12, 2018 & Aug 14, 2018

Eternity Costs and Wicked Legacies: Unacknowledged Constraints to a Sustainability Transformation?

Organizer:
Verena Winiwarter (University of Natural Resources and Life Sciences, Vienna)

The fossil fuel-based way of living has enabled society to gain unprecedented control over materials and develop multiple technologies. Its side effects are likewise unprecedented. A sustainability transformation envisaged as the way out of this conundrum is operationalized in the Sustainable Development Goals (SDGs) on a global level.
While the introduction to the SDGs claims that the negative impacts of urban activities and of hazardous chemicals should be reduced, the document is devoid of any systematic treatment of the legacies of the industrial mode of living which have developed since the 1850s at the very latest.
In this exploratory workshop, experts from different fields discussed the complex and wicked issue of long-term legacies that might compromise any sustainability transition. The participants were invited to identify possibilities to address these issues in joint research, using the potential of Big Data and of a long-term view on side effects as employed in environmental history.
At the follow-up meeting in August, workshop participants further discussed questions like: How can the problem be modeled to simulate the effects of legacies and countermeasures? How can the severity and scale of the problem be communicated?

July 31–Aug 1, 2018

Experimental vs Information-Theoretic Approach to Complex Systems

Organizer:
Jan Korbel (Medical University of Vienna & CSH Associate Faculty)

In recent decades, complex systems and complexity in general started to play a crucial role in the description of real physical, biological, and socioeconomic systems. However, the description of complex systems, its classification, and modelling remain open problems in many applications. One of the possible approaches is to use the results from information theory. They provide us with a general framework enabling the measurement and characterization of the structure and dynamics of a given system. The aim of this workshop was to discuss applications of information theory, especially entropic measures in various fields as physics, biology or financial markets, and to stimulate collaboration.

Sept 6–7, 2018

Machine Behavior

Organizer: David Garcia (CSH)

This workshop seeks to contribute to the foundation of the new discipline of Machine Behavior: the scientific study of behavior exhibited by intelligent machines. This discipline will study intelligent software and hardware agents not as products of engineering, but as actors that should be empirically analyzed to reveal their behavioral patterns.
An interdisciplinary set of pioneers in the study of the behavior of intelligent agents met at the CSH to set the research agenda to follow in the next years. They added an extra focus on how to tackle the inherent complexity of expert systems, intractable software, and multi-agent systems in which software bots coexist and interact with humans.

Sept 11, 2018
CSH–ETH Workshop

1st City Olympics

Organizers:
Dirk Helbing (ETH Zurich & CSH External Faculty)
Stefan Thurner (CSH)

Cities and social communities can be important agents of global change. How can a participatory approach contribute to reaching the United Nation's Sustainability Goals, as laid out in the Agenda 2030, the Paris Climate Accords, and elsewhere?
An effective way could be to organize City Olympics: an event where cities around the world and the regions around them would regularly compete for the best environmental-friendly, energy-efficient, resource-saving and crisis-proof solutions. After the competitive phase of each City Olympics, there would be a cooperative phase, where the best ideas, technologies, and urban governance concepts would be exchanged among the participating cities. Moreover, if the resulting innovations would be under the Creative Commons license and open source, the solutions could be easily further developed by everyone. This would lead to new businesses and a fast and widespread adoption of the best solutions.

Oct 1, 2018
CSH–CEU Workshop

Vienna Meets Budapest

Organizers:
János Kertész (Central European University & CSH External Faculty)
Stefan Thurner (CSH)

Researchers from the Complexity Science Hub Vienna and the Center for Network Science at Central European University Budapest (CEU) discuss further areas of cooperation. The workshop took place in Budapest, Hungary.

Dec 13, 2018
CSH–OFAI Workshop

Artificial Intelligence and Complexity Science: A First Meeting

Organizer: Robert Trappl (Austrian Research Institute for Artificial Intelligence OFAI)

The aim of the meeting with Robert Trappl's team from the Austrian Research Institute for Artificial Intelligence was to explore potential future co-operation.

Jan 22, 2019

Developing Accountable Systems

Organizer: Anniko Hannak (CSH)

Researchers working on bias and accountability in algorithmically aided systems discussed examples of systems where algorithms can be harmful, how users' perception and interactions with these services affects outcomes and explored research ideas and opportunities for designing accountable systems. The discussions were structured around relevant practical examples, such as algorithmic decision-making in job search, route planning services, and the role of algorithms in food delivery services.

Feb 18, 2019

CSH–IIASA Exploratory Workshop

The aim of the meeting, which took place at the International Institute of Systems Analysis (IIASA) in Laxenburg, was to explore fields of future co-operation.

Feb 19–20, 2019

Scientific Evolutionary Writing

Organizer:
Vittorio Loreto (Sapienza University of Rome & CSH)

All scientific research involves attempts to resolve a mystery, overcome an obstacle, or solve a problem. This makes them stories with narrative potential. But most scientific papers lack basic story-telling mechanisms.
This workshop, led by two renowned science writers, explored story-telling techniques and how they can be used in scientific papers while maintaining the scientific rigor required for the world's top journals. Participants were challenged to embark on an evolutionary process of their creations to rewrite and refine their texts to a point at which "texts can only be worsened."

Feb 21–22, 2019

Current Challenges in Non-Linear Regulatory System Dynamics and Evolution

Organizers:
Rudolf Hanel (Medical University of Vienna & CSH Associate Faculty)
Stefan Thurner (CSH)

This workshop intended to advance an understanding of the interplay between the structure, dynamics, and evolution of non-linear regulatory systems which can be found in a broad spectrum of essential processes, such as the regulatory dynamics of cellular organisms at a molecular level, but also at a species level. Theoreticians and biologists were brought together in an attempt to match interests in and knowledge about such systems from both sides. The idea was to first sketch how mathematical models of regulatory networks naturally involve non-linear dynamical aspects, and the phenomenological consequences one would hence expect. This includes a discussion of dynamical stability, attractor landscapes and multi-stability in large regulatory systems, and "evolutionary forces" that may govern the emergence of modular regulatory components in the course of evolution. Second, related aspects were discussed from the biologists' perspective.
One aim was to better understand some exceptional datasets which in combination with methods from non-linear dynamical systems theory have the potential for analyzing dynamical gene regulatory systems.

Apr 29–May 1, 2019

Information-Theoretic Methods for Complexity Science

Organizers:
Jan Korbel (Medical University of Vienna & CSH Associate Faculty)
Stefan Thurner (CSH)
Petr Jizba (Czech Technical University in Prague)

To what extent and how can methods from information theory and (non-equilibrium) statistical physics boost the understanding of complex dynamical multilevel systems? The workshop aimed to fathom the limits of usefulness of thermodynamics for complex systems and discuss if there are fundamental limits to a statistical theory of complex systems.
In particular, it focused on the questions: What is the use of entropies for complex, driven and out-of-equilibrium systems and networks? What must thermodynamics of complex systems be able to do? How can we use information geometry in complex systems? Is information theory in the context of complex systems more than just a framework? Can we compute things that we could not do otherwise? Can we use information geometry for a classification of complex and out-of-equilibrium systems? What is the aim of such a classification?

May 23–24, 2019

Towards a Theory of Health Trajectories from Longitudinal Data

Organizers:
Peter Klimek (Medical University of Vienna & CSH)
Stefan Thurner (CSH)
Nils Haug (Medical University of Vienna & CSH)

Patient health is typically characterized by a combination of clinical conditions and diseases. Often these diseases do not occur independently from each other but in specific temporal patterns. The increasing availability of large-scale observational healthcare data, e.g., electronic health records and claims data, triggered increasing interest in the problem of how to mine such data for temporal patterns and how to use this information to build predictive models for disease trajectories. This workshop aimed at bringing the world's leading researchers together to work on these and related questions in order to discuss open problems and recent advances in an informal atmosphere.

June 28, 2019
Brainstorming Workshop

Artificial Intelligence

The goal of this internal meeting was to take stock of existing AI activities at the Hub and to discuss areas in which new research groups could get involved synergistically with existing groups.

July 22, 2019

Spatially- and Time-Resolved Experimental Complex Systems

Organizers:
Jan Korbel (Medical University of Vienna & CSH Associate Faculty)
Dalibor Štys (University of South Bohemia, Czech Republic)

Owing to its excellent spatial and temporal resolution, video analysis belongs to the main methods to investigate complex systems. In principle, optical image sequences simultaneously provide both time-resolved information and spatial distribution of electromagnetic spectra. This information is technically limited, which may impact a proper understanding of the evolution of the structure of a complex system. Technical limits are a frequency of image capture, spatial resolution and, subsequently, the possibility to reconstruct the spectrum of the object.
The workshop dealt with the model of a self-organized chemical system, the Belousov-Zhabotinsky reaction. It presented an influence of change of the timestep and object size on the objective definition of states in which the system evolves in time; the progress in 3D microscopy of living cells and tissues using multifractality assumption and the progress in spectral reconstruction of observed cell interior; the progress in the research of fish school behavior (down to the role of individuals, quantifying their preferences and feelings). Another aim was to substantiate a research direction that has a practical impact on image analysis, medicine, ethology, security research, etc., but still lacks a comprehensive fundamental research foundation.

Aug 5–7, 2019

How Can We Reduce Cyberhate?

Organizer: David Garcia (CSH)

Online hate or cyberhate refers to a behavior in which people send extreme, harassing, threatening, or insulting messages concerning, for example, sexual orientation, religious conviction, ethnic background, disability, appearance, or gender to intentionally hurt others. This kind of aggressive behavior can lead to serious short- and long-term consequences for individuals and societies, including increased terrorist-group activity, discrimination against minorities, violent conflicts, or even war. Online hate and extremism are increasing global phenomena. It is important to discover how people become its perpetrators, how to prevent them from perpetrating online hate as well as how victims can effectively cope with online hate.
Integrating scientific and multidisciplinary understanding of online hate, the workshop aimed at setting up a framework to analyze the extent of online hate globally, as well as its consequences for people and societies, with the final purpose to discover, test, and decrease online hate and minimize its harms.

Sept 12–13, 2019
CSH–KLI Workshop

Sustainability as a Problem of Complexity

Organizers:
Manfred Laubichler (Arizona State University & CSH External Faculty)
Guido Caniglia (Konrad Lorenz Institute KLI, Klosterneuburg)

Popular ideas about sustainability are still largely guided by a techno-scientific ideal of control, even though limits and difficulties of this ideal have been obvious for some time. Often fueled by alarmist scenarios of destruction, the remnants of a techno-scientific ideal of control threaten to undermine the very notion of sustainability, as well as our attempts to initiate and foster transformations towards more desirable and just futures.
Alternatives to a techno-scientific illusion, such as co-evolutionary processes within complex adaptive systems or participatory transdisciplinary conceptions of sustainability, have emerged, but have yet to gain wider acceptance outside of specific academic discourses.
This workshop placed current ideas about sustainability and related transformations in the context of interlinked histories of techno-science, cybernetics, complex systems theory and sustainability science. Participants focused on detailed historical analyses of case studies, the assessment of current trends and discourses, and the envisioning of future ones. Another focus was on the shifting conceptual frameworks and on the role of modelling strategies (especially complex systems models) for sustainability transformations. The goal of the workshop, which took place at the Konrad Lorenz Institute (KLI) in Klosterneuburg, was to jointly develop a more adequate methodology and epistemology for a sustainability science that moves beyond a techno-scientific ideal of control and that is rooted in complex adaptive systems, co-evolutionary perspectives, and transdisciplinary methodologies.

Oct 17–18, 2019

Modelling Neolithic Crises

Organizer:
Peter Turchin (University of Connecticut & CSH External Faculty)

As knowledge of Neolithic populations becomes more quantitative, several research teams have proposed that the population dynamics of groups that switched from foraging to agriculture and animal husbandry do not fit the older idea of a monotonic increase towards carrying capacity. Detailed regional archaeology supports the idea that there were repeated cycles of social complexity linked with population dynamics.
The workshop addressed the possible causal explanations of Neolithic cycles. It focused on three hypotheses: (1) an exogenous forcing of population ups and downs due to climate variability, (2) an endogenous boom–bust dynamic resulting from feedbacks between population and agriculture, and (3) an endogenous cycle between population and warfare.
This approach intends to combine model development (translating each hypothesis, as well as their combinations, into a suite of agent-based models) with empirical case studies.

Oct 21–22, 2019
Planning Workshop

Historical Dynamics of Social Norms and Sentiments Underlying Cooperation

Organizer:
Peter Turchin (University of Connecticut & CSH External Faculty)

The overwhelming majority of approaches testing various hypotheses about social resilience focus on “hard” data, such as climate change, food, and water supply, demographic rates, trade and financial systems, and economic inequality. But what about difficult-to-quantify cultural and psychological processes that may also help us understand why people sometimes cooperate and, at other times, cooperation breaks down? Besides physical, demographic, and economic factors, we also need to investigate the possible role of such mechanisms.
One quantity that may be a key to understanding human resilience in the face of societal threat is the strength of social norms. How do we identify possible causal mechanisms that strengthened or weakened norms over the long run, and determine the relationship between norm strength and social outcomes? How do we investigate and measure emotive drivers of social breakdown and cohesion? Why is cooperation at the level of the whole society/polity sometimes strong (and is supported by strong cooperative norms), and at other times unravels, with most people shifting their loyalty and cooperation to narrow, partisan groups? How does culture affect the ways in which communities perceive and respond to social crisis?
The goal of the workshop was not to solve these difficult questions, but to conduct a multidisciplinary conversation between diverse fields (anthropology, social psychology, semiotics, history, and cultural evolution).

Nov 25–26, 2019

Higher-Order Connectivity and Correlations in Complex Systems

Organizers:
Álvaro Corral (Centre de Recerca Matemàtica, Barcelona & CSH External Faculty)
Bosiljka Tadić (Jozef Stefan Institute, Ljubljana & CSH External Faculty)

The emergence of new features in evolving complex systems highly correlates with their cooperative response to the driving forces, which also leaves characteristic patterns in time-varying data. Collective dynamics of this kind can arise from non-trivial connections that go beyond standard pairwise interactions in the network that underlies the dynamics. This higher order architecture can be described with simplexes of different types and quantified by using advanced algebraic topology methods. For a given system, complexes made of these geometric descriptors represent its unique functional topology. Remarkably, the underlying networks, as 1-skeleton of simplicial complexes, have a hyperbolic geometry, a feature that can be linked to an improved function.
The workshop goal was 1) to discuss the simplicial complexes representation of various complex systems, and 2) their dynamical complexity. By addressing mathematical and theoretical concepts and empirical data analysis, the discussion aimed to provide new answers to open problems, specifically, to reveal the implications of higher-order interactions for the dynamics; to find the relevant information through the topological data analysis, and to make these topological approaches to complexity more recognizable.

Dec 10–12, 2019

Using Mobile Telephony Data for Societal Insight

Organizer:
Allan Hanbury (TU Wien & CSH)

The sensor in the form of a smartphone carried by the majority of citizens has the potential to deliver insights into various aspects of society in an unprecedented way. The data can be analyzed directly to characterize society or used to accurately parametrize agent-based models. Insights can be obtained in the areas of health science, social science, disaster management, and mobility, amongst others. However, the use of this data usually elicits extreme skepticism on the part of the companies owning the data and the end users of the smartphones, which usually leads to less-than-optimal usage of such data in countries with strict privacy regulations.
The main question to be answered by the workshop was: How can data gathered from mobile telephony be used to obtain the deepest insights into the functioning of society, while being gathered in such a way that its use is acceptable or even welcomed by members of society? The workshop identified key application areas, technical measures to guarantee privacy and security of the data, as well as measures to increase the acceptance of data usage to members of society as well as policy-makers.

Feb 10, 2020

Bringing Intelligence to Networked Embedded Devices

Organizer:
Olga Saukh (CSH)

Machine learning is the key enabling technology for many Internet of Things applications. However, making machine learning models operate reliably in the physical world faces unique challenges. Collection and processing of sensor data to build an accurate machine learning model is difficult for embedded devices due to their resource constraints, privacy threats and bandwidth limitations. The challenge gets even more severe if the data are noisy and decentralized. Machine learning also plays an important role in adapting the parameters of the deployed networked embedded devices to environmental dynamics.
The workshop focused on how to address these challenges and bring intelligence to networked embedded systems.
Participants discussed the current state of ongoing research projects in this area and planned collaborations across research groups co-affiliated with Graz University of Technology.

May 27–29, 2020
First CSH Online Workshop

Stochastic Thermodynamics of Complex Systems

Organizers:
Jan Korbel (Medical University of Vienna & CSH)
David Wolpert (Santa Fe Institute & CSH External Faculty)

Stochastic thermodynamics is a powerful extension of conventional equilibrium statistical physics designed for analyzing non-equilibrium thermodynamics of small systems, down to the level of individual trajectories. In stochastic thermodynamics, we typically consider a system undergoing a continuous-time Markov process while coupled to (one or more) infinite heat, particle, or work reservoirs. If there is a single infinite heat reservoir and local detailed balance holds, then the equilibrium distribution is the ordinary Boltzmann distribution. Yet, in many complex systems, the equilibrium distribution is different from the Boltzmann distribution. These kinds of equilibria arise because the reservoirs are finite, the dynamics are non-Markovian, or some other assumption of conventional stochastic thermodynamics is violated.
The workshop, due to COVID-19 pursued as an online event, investigated questions like: What are the necessary and sufficient conditions for a thermodynamic system to have a non-Boltzmann equilibrium distribution? What equilibria arise if we extend conventional stochastic thermodynamics, e.g., to involve non-linear master equations? How can we experimentally test such extensions of conventional stochastic thermodynamics? Do we need to generalize the concept of entropy to analyze these scenarios? What is the role of the maximum entropy principle in these scenarios?

▶ The presentations were recorded and can be seen on our YouTube channel.

Aug 20, 2020

CSH–ICS Meeting & Workshop

Organizers:
Jan Korbel (Medical University of Vienna & CSH)
Dalibor Štys (University of South Bohemia, Czech Republic)

At this small meeting and workshop, co-organized with the Institute of Complex System ICS (University of South Bohemia, Czech Republic), participants discussed questions arising from the use of optical microscopy; inverse problems, and optical spectra reconstruction in practice; the use of a wide-field bright-field light microscope to recognize intoxicated from unintoxicated cells; the possibilities and limitations of using an information theory approach to living objects’ behavior; and the thermodynamics of systems with emergent structures.

Feb 10–11, 2021
CSH co-hosting the

Virtual COVID-19 PHSMs Data Coverage Conference – Part I

Co-Organizer:
Amélie Desvars-Larrive (University of Veterinary Medicine, Vienna & CSH)

In Spring 2020, various groups, organizations, researchers, and volunteers around the world started to collect data on governmental public health and social measures (PHSMs) made in response to COVID-19. The groups assembled huge databases that have already proven themselves in dealing with the challenges of the current pandemic.
The largest PHSMs tracker, the CoronaNet Research Project (TU Munich), initiated a two-part workshop and conference which was co-hosted by the Hub (which has complied its own database, the CSH Covid-19 Control Strategies List CCCSL) and three other trackers.
Part I of the meeting, a more technical two-day workshop in February, was designed to bring together the relevant stakeholders with the aim to discuss current challenges in data collection, data quality and data coverage, explore potential ways to cooperate, and share funding opportunities among different trackers. The participants also discussed guidelines for navigating the taxonomy for PHSMs and explored possibilities of collaboration or coordination. It was followed by a public conference on March 3, 2021.

Cancelled or Postponed Due to Corona

Building Non-Euclidian Spaces to Measure, Understand, and Navigate Complex Social Transitions

Organizers:
Shade Shutters (Arizona State University) and Carlos Molinero (CSH)

Cancelled or Postponed Due to Corona

Understanding Online Emotional Communication

Organizers:
David Garcia (CSH) and Mark Strembeck (Vienna University of Economics & Business & CSH)

Cancelled or Postponed Due to Corona

Communicating Complex Climate Issues with Deliberative Democracy

Organizers:
Karoline Wiesner (University of Bristol & CSH External Faculty) and David Garcia (CSH)

Cancelled or Postponed Due to Corona

Stochastic Dynamics for Complex Systems

Organizers:
Christian Kühn (Technical University of Munich & CSH External Faculty), Maximilian Engel and Alexandra Neamtu (Technical University of Munich)

Talks & Web talks

The Hub regularly hosts talks and lectures. See what our guests and visitors, our scientists, our students, our affiliates, and friends are reflecting upon and researching about.

2016

June

Robert Kreuzbauer
Behavioral micro-theories: Identifying best signaling strategies to examine cultural equilibria

September

J. Stephen Lansing
Adaptive self-organized criticality in Bali's ancient rice terraces

2017

April

David Wolpert
Reducing the error of Monte Carlo algorithms by learning control variates

David Wolpert
Thermodynamics of computation: Beyond bit erasure

János Kertész
Multiplex modeling of the society

Leonhard Horstmeyer
Understanding epidemic transitions by means of moment closures

Ivan Smirnov
Segregation by academic performance in the digital space

Rudolf Hanel
Process, history dependence, and entropy

May

Wouter Beek
LOD Lab: Experiment at web scaleby

Tamás Biró
Unidirectional and resetting stochastic dynamics

Kimmo Kaski
Social physics: Data-driven discovery of human connectome

Eugenio Valdano
The spread of diseases on time-evolving networks

W. Brian Arthur
Combinatorial evolution

Sander van der Leeuw
The information society as a complex system

Constantino Tsallis
Nonadditive entropy

June

Leonhard Horstmeyer
The Gillespie algorithm

Axel Polleres
Open data as the fuel for complexity science?

Anton Pichler
Minimizing systemic risk as an optimal network reorganization problem

Sandra Blakely
Samothracian networks: Maritime risks and ritual promises in an ancient Mediterranean context

Sebastian Poledna
Economic forecasting with an agent-based model

J. Stephen Lansing
Islands of order

Abraham Hinteregger
Systemic risk in the Austrian economy

July

Mark Strembeck
From security engineering to the (security) analysis of complex networked systems

August

Javier Fernandéz
Democratizing big semantic data management, or how to query a labeled graph with 28 billion edges in a standard laptop

September

Luca Rade
Precursors to transitions in an adaptive network

Imre Kondor
An analytic approach to regularized portfolio optimization

Sherif Sakr
Big RDF processing systems

Tamer Khraisha
Evolution of innovations on fitness landscapes

November

Johannes Sorger
Visualization integration strategies: Theory and practice

Sebastian Poledna
Linking natural disasters with socio-economic systemic risk through a data-driven agent-based model

Terano Takao and Hiroshi Deguchi
Agent-based modeling of complex systems

Olga Saukh
Sensing the air we breathe

Nino Lauber
Do small evolutionary systems innovate faster?

December

Leonhard Horstmeyer
On the Jain and Krishna model

Shlomo Havlin
Cascading failures and recovery in interacting networks

Michael Gastner
A fast flow-based algorithm for creating density-equalizing map projections

2018

January

Nils Haug
Predicting human disease trajectories

Vasyl Palchykov
Human mobility and communication patterns: An agent-based modeling approach

Vinko Zlatić
Unexpected properties of color avoiding percolation

February

Janusz Holyst
Phase transitions in coupled networks

March

Stefania Monica
KTMAS: Analytics modelling of the dynamics of multi-agent systems

Sharwin Rezagholi
Some data on electoral competition and a toy model

Simon Schweighofer
Affect and political polarization

Ryan Boyd
The arc of narrative: The objective quantification of story structure

April

Salil Kanhere
Converting your thoughts to texts: Enabling brain typing via deep feature learning of EEG signals

Maarten Vanhoof
Mobile phone data, networks, and space

Milan Palus
Information transfer across time and scales

Leonhard Horstmeyer
Novel insights into the precursor theory of adaptive networks

Carlos Molinero
The efficiency of road networks

May

Verena Winiwarter
Eternity costs and wicked legacies: Unacknowledged constraints to a sustainability transformation?

Jan Korbel
Consistency of the maximum entropy principle for generalized entropies

Jan Korbel
Transitions between superstatistical regimes

David Garcia
Affective intelligence in online political discussion forums

José Fernando Mendes
A unified approach to percolation processes on multiplex networks

Peter Klimek
Counter-dominance signaling drives evolution of cultural elites: Quantitative evidence from fashion cycles in music

Chris Baker
Peak stuff and permafrost: Critical transitions in eco-environmental interactions

June

Nils Haug
Forecasting human disease trajectories with healthcare networks

Luca Rade
The evolution of complex ecosystems, and the future of AI

Julya Neidhardt
Social influence and opinion forming in online social networks

Stefan Pfenninger
Designing an energy system based on variable wind and solar power

Johannes Sorger
An introduction to visualization research and the EuroVis 2018 conference report

July

Carlos Pineda
The random nature of rank dynamics

Armen Beklaryan & Andranik Akopov
Review of developing simulation models for decision making systems for economic, social, and ecological planning

August

Balz Maag
Equipping wearables with low-cost environmental sensors for personal sensing applications

Danny Arlen de Jesús Goméz-Ramiréz
Towards artificial mathematical intelligence and the foundations of cognitive metamathematics

September

Tuan Pham, Leonhard Horstmeyer and Ruggiero Lo Sardo
Quantization: A novel precursor for collapses of ecosystems

Christoph Fabianek
Data mobility

October

Peter Turchin
What history tells us about our age of discord

Nino Lauber
Influence of the group size on the rate of combinatorial innovation production

Semeen Rehman
Dependable, energy-efficient, and intelligent embedded computing for the Internet of Things

Ladislav Kristoufek
Looking for fundamentals in Bitcoin price

Francisco A. Rodrigues
Epidemic processes in single and multilayer complex networks

November

Rudolf Hanel
Understanding driven and irreversible processes

Michael Miess
Economic forecasting with DSGE models: An evaluation and critique

Simon Schweighofer
The measurement of meaning

Tom Carlowitz
The effect of food price inflation on Twitter sentiment in Nigeria

Manfred Klaffenböck
Facilitating research in visual parameter space analysis through rapid suggestive visualization prototyping

Belgin Mutlu
Methods to recommend and personalize visualizations

December

Leonhard Horstmeyer
Precursor theory of adaptive networks

Martin Proks
Revisiting transitions between superstatistics

Markus Strauss
Data-driven identification of disease phenotypes using higher-order correlations

Mirta Galesic
The complexity of diversity

Henrik Olsson
Collective intelligence: The role of group size and individual strategies

2019

January

Fabian Wagner
Ideas for future CSH and IIASA collaborations

Jan Korbel
Scaling expansions: Universal tool for classification of complex systems

Tuan Pham
A brief review on a generalized model of epidemic spreading

Torsten Heinrich
Agent-based models of industrial organization and technological change

Fabian Flöck
Social media data for the social sciences: A preliminary error framework and some use cases

February

José Morán
SSR processes, multiplicative growth, and power laws

March

Johannes Preiser-Kapeller
Micro-histories, macro-dynamics, and the contested study of medieval societies

Grigore Stamatescu
Data-driven modelling of large-scale manufacturing systems

Peter Klimek
Quantifying economic resilience from input-output susceptibility to improve predictions of economic growth and recovery

Bernard Rimé
Emotional synchronization, social integration, and health

Caspar Matzhold
How interdisciplinary research promotes data-driven analysis

Kristina Lerman
Simpson's paradox in social data

April

Borut Trpin
Belief updating in untrustworthy circumstances

Leonardo Zavojanni
Prediction of human behavior in the multiplayer online game Pardus

May

Max Pellert
Emotional expression dynamics in social media

Sibel Eker
Modelling human behavior behind global diet shifts

Nils Haug
History-dependent modeling of patient health trajectories

Christian Poellabauer
Speech as barometer of the brain

Ruth Pfeiffer
Using electronic medical records for epidemiologic research: Opportunities, challenges, and examples

Václav Zatloukal
Local time of random walks

Christoph Stadtfeld
The micro–macro link in social networks

Jan Korbel
Predicting collapse of networked systems without knowing the network

June

Rosario Mantegna
Trading networks and investor's ecology in a fully electronic stock market

Hiroshi Matsuzoe
Geometry of estimating functions on deformed exponential families

Olga Saukh
Quantle—fair and honest presentation coach in your pocket

Simon Schweighofer
A balance model of opinion hyperpolarization

Tuan Pham
Opinion formation and structural balance on co-evolving signed networks

September

Carlos Molinero and Simon Rella
How fractal geometry determines urban scaling laws

Grigore Stamatescu
Deep impact models for edge characterization of energy events

October

Henrik Olsson
Predicting the 2018 US House of Representatives elections based on social-circle expectations, state-expectations, and Bayesian Truth serum

Mirta Galesic
An integrative modular framework for belief dynamics

Franz Neffke
Diffusion and coordination of complex knowledge

Jim Bennett
A model of agrarian state-nomadic confederation interaction in the Old World

Célian Colon
Coupling transport and supply chains to analyze the impact of disasters: An application to the United Republic of Tanzania

William Schueller
Active control of complexity growth in a multi-agent model

Martin Polz
How interactions structure microbial diversity from genes to ecosystems

Helena Milton
Explaining the spread and persistence of maladaptive medical beliefs

Vera Hemmelmayr
Location and routing decisions for a collaborative recycling network

November

Jenny Reddish
Introduction to Seshat Global History Databank

Miguel Centeno
From global risk to collapse

Yvonne-Anne Pignolet
Elites in social networks: An axiomatic approach to power balance

Anna Di Natale
Colexification networks

David B. Saakian
Solving the evolutionary dynamics on fluctuating landscapes

Bernat Corominas-Murtra
The problem of the copy in information theory

Andrew Ringsmuth
Towards resilience from local to global: The challenge of scale in social-ecological system dynamics

Balázs Lengyel
Inequality is rising where social network segregation interacts with urban topology

Christian Diem
Optimal financial networks and measuring systemic risk in multilayer networks

December

Tiago Teixeira dos Santos
Self- and cross-excitation in stack exchange question and answers communities

R. Maria del Río-Chanona
Occupational mobility and automation: A data-driven network model

Stefan Schmid
Self-adjusting networks

Christiane Puchhammer
Embryonic mouse development

2020

January

Simon Lindner
Entropy and multiplicity on the basis of the magnetic coin model

Victor Galaz
Our planet on the edge: Can technology really save us?

Niklas Reisz
Information flow processes in complex systems

Erwin Flores Tamés
Supply chain ID with payment data

David Wolpert
Uncertainty relations and fluctuation theorems for Bayes nets

February

Achim Edelmann
What shapes scientist's position taking in contested public debates?

Fariba Karimi
Structure of social networks influences ranking and perception of minorities

Ivan Smirnov
Inequality and well-being in the digital age

March

Christiane Puchhammer
Dimensional reduction through metric pseudo-time

CSH Webtalks

Corona put an abrupt end to our live events. We continued by inviting people from the Hub and from the rest of the world to give us virtual talks.

2020

May

Rahim Entezari
Understanding deep model compression for IoT devices

June

Johannes Wachs
Social complexity and resilience in open source software

Ladislav Kristoufek
Environmental impacts of Bitcoin mining: Some new evidence

Franz Papst
Privacy-preserving machine learning

Tobias Reisch
Gender differences in coping with a pandemic

July

Robert Paluch
Maximum likelihood approach for location of the epidemic source in complex networks

August

Ulf Leonhardt
Casimir cosmology: How the force that limits the height of trees accelerates the expansion of the universe

András Borsos
Shock propagation in the banking system with real economy feedback

September

Ramin Hasani
Time-continuous neural networks

Johanna Einsiedler
Estimating the impact of COVID-19 on air pollution with interpretable predictive models

Patricia Palacios
Can physics tell us something about democracy?

October

Eszter Pázmándi
Systemic risk

Limor Raviv
Psychology of language department

Teresa Farinha
Impacts from automation diffuse locally: A novel approach to estimate jobs risk in US cities

Anna Di Natale
Colexification networks encode affective meaning

November

Anna Wegmann
Detecting different forms of semantic shift in word embeddings via paradigmatic and syntagmatic association changes

Jana Lasser
Efficient testing strategies to prevent the spread of SARS-CoV-2 in nursing homes

Zoltán Elekes and Gergo Tóth
Technology network structure conditions the economic resilience of regions

December

Hannah Metzler
Collective emotions during the COVID-19 outbreak

Jean-Philippe Bouchaud
Marginally stable economies?

Dirk Brockmann
Understanding the Covid-19 pandemic: Math, models, mobility, and taking a nation's temperature

2021

January

Jan Hurt
Economic recovery with price-quantity dynamics in an agent-based input–output model

Gülce Kardes
Thermodynamic uncertainty relations for multipartite processes

Miguel Fuentes
Anomalous diffusion, evolution, and innovation

Bastian Wurm
Organizational complexity: A computational social science perspective

Elma Dervic
Modelling dynamical comorbidity networks from longitudinal healthcare data

February

Vincent Traag
Inferring the causal effect of journals on citations

Nicolás Robinson-García
Task specialization across research careers

Shade Shutters
From Panarchy to practice: A complexity approach to understanding urban resilience

Jana Lasser
Agent-based simulations of SARS-CoV-2 prevention measures in schools

March

Jan Korbel
Stochastic thermodynamics of complex systems

Gülce Kardes
Thermodynamic uncertainty relations for multipartite processes

Stéphane Hallegatte
Modeling the impact of natural disasters on poverty

Niklas Reisz
Kouzan app relaunched: Tracing the intangible

CSH Winter Program

This is the plan: to offer graduate students, PostDocs, and other interested people with a scientific background some days of intensive morning and afternoon classes with internationally renowned complexity scientists...

...eased by afternoon skiing, sauna, good food, and evening fireside chats in the inspiring environment of the Austrian High Alps—because what else could a winter school in Austria be but a journey to the mountains? And so it happened, that the Hub held its first winter school in Tyrol.

2019 CSH WINTER SCHOOL

27 young scientists from Mexico to Italy, from England and Germany to Austria and France, followed our invitation to spend five great days in Obergurgl with us (in March 2019). Getting up early was the hardest part—the morning lectures started at 8 o'clock already. But the long afternoon breaks with skiing, walking, or getting swallowed up by deep snow made up for this. The hungry ones began hunting for typical Austrian specialties (Kaiserschmarren! Käsespätzle!), others got involved in literally hot discussions during extended sauna sessions before they all came back together for the afternoon classes.

With mountains and glaciers gleaming outside the window, the young men and women learned about network theory from Vito Latora (London School of Economics & CSH External Faculty) and microbial terraforming from Ricard Solé (Universitat Pompeu Fabra in Barcelona & CSH ExF). They were introduced to complex biology by Eörs Szathmáry (Eötvös Loránd University, Budapest) and the theory of complex systems by Stefan Thurner. To top it off, Roberta Sinatra, at that time a freelance scientist in Copenhagen (and CSH ExF), introduced to the science of success.

After truly delicious dinners, the participants had the chance to experience Constantino Tsallis's humorous "fireside chatting" (without a fire—it would just have been too hot in that tiny room...). Constantino, a complexity veteran from Rio de Janeiro, even skipped carnival for that.

The spirit was fantastic, the feedback was great—so we immediately booked the rooms for a second edition in 2020. Then a certain virus got in the way...

2021 CSH WINTER LECTURE SERIES

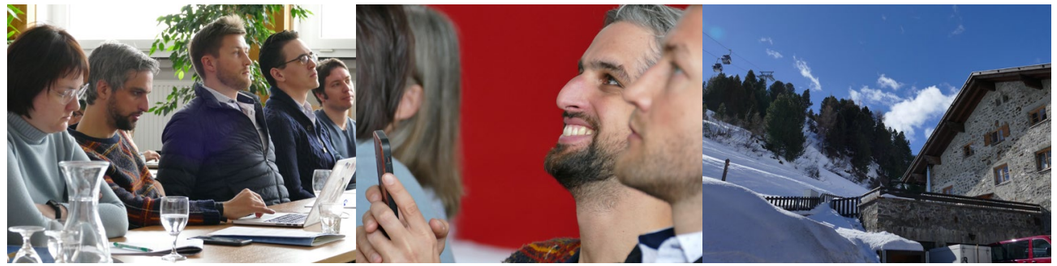
When it became clear that we would not be having a live winter school in 2021 either, we decided to switch worlds: from winter wonderland to World Wide Web, from the Alps to Zoom. And while we were naturally sad that we had to go without snow this year, the virtual gathering at least offered an opportunity to interested people worldwide to take part as additional listeners.

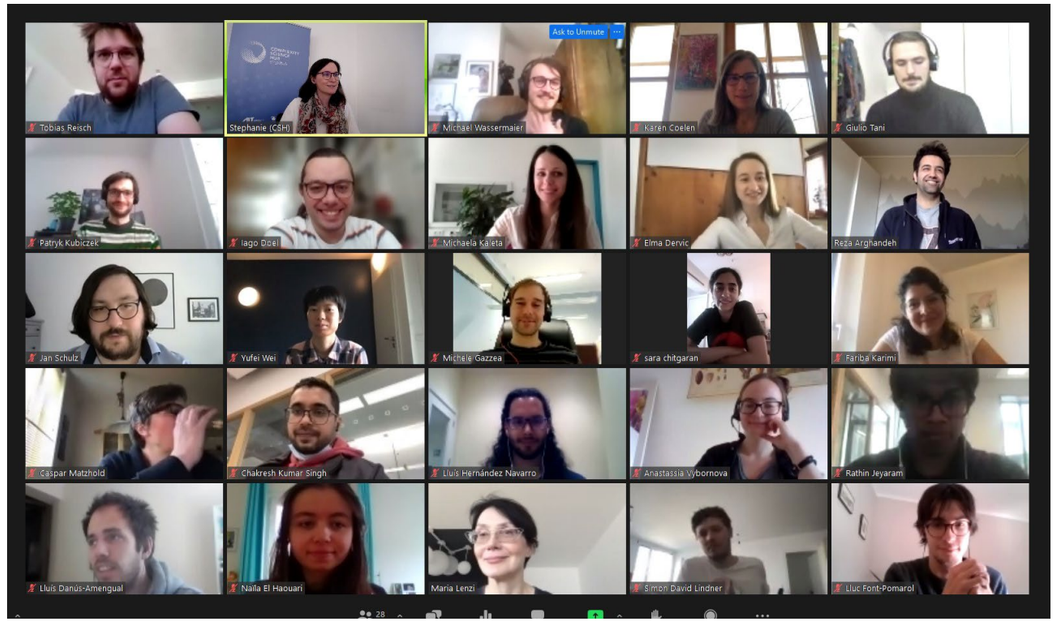
We had four days of high-quality online lectures, 16 hours of live academic Zoom sessions, and these great speakers: Simon DeDeo (Carnegie Mellon University & CSH ExF) provided an insight into cultural data science. Fariba Karimi (CSH & Central European University) discussed current advances in computational social science. Vittorio Loreto (CSH & SONY-CSL Paris) explored the dynamics of novelty and innovation. Renaud Lambiotte (University of Oxford & CSH ExtF) discussed the dynamics and modularity of network science and higher order networks. And Andrea Rapisarda (University of Catania & CSH ExtF) explored the beneficial role of randomness.

To mimic the flair of a live event that fosters engagement, networking, and direct dialogue with the speakers, we used "Wonder," a funky, free tool that allows people to move freely from "table to table" as avatars, join the groups they are interested in, and start a discussion with speakers and other participants. Everyone enjoyed this very much (and the snowy summit picture as a backdrop even gave the networking sessions some alpine flair...).

Our 39 extremely engaged winter school participants and the 18 additional listeners, spanning from the US East Coast to India and Australia, awarded the virtual event top marks. They praised the variety and interdisciplinary of the lectures and the great interaction with the speakers. Some even formed a Telegram group to continue exchanging new ideas gained from the event and, some day, maybe meet in person.

Everybody was happy. And we are sure: It won't be the Hub's last event of this kind (although we are of course planning a next winter school in the Alps, too!).





(Image Top Right) Great fun: The first CSH Winter School in Obergurgl/Tyrol (2019)

(Image Bottom Right) Smiles all around! "Zoom group picture" at the end of the first CSH Winter Lecture Series

Visitors

The ABC to Z of scientists, politicians, opinion and other leaders, authorities, experts, and friends who visited the Hub between May 2016 and May 2021.

Aberer Karl, EPFL Lausanne, Switzerland (May 2017)
Abson Dave, Leuphana University Lüneburg, Germany (Sept 2019)
Akhmetzhanova Aizhan, Princeton University, USA (June–Aug 2019)
Akopov Andranik, NRU Higher School of Economics, Moscow, Russia (July 2018)
Altenberg Lee, University of Hawaii at Manoa, USA (May 2016)
Andersson Bertil, Nanyang Technological University Singapore (May 2016)
Andjelkovic Miroslav, INS Vinča, Serbia (Nov 2019)
Androsch Hannes, Androsch International Management Consulting GmbH, Austria (June 2017)
Arenas Alex, Universitat Rovira i Virgili, Spain (Oct 2016)
Artemov Artem, Medical University of Vienna, Adameyko Lab, Austria (Feb 2019)
Arthur W. Brian, Santa Fe Institute, USA (May 2017, April 2018, June 2019)
Asam Dominik, Infineon Technologies Austria (Dec 2016)
Avrilionis Denis, Compell.io, Luxembourg (May 2018, Sept 2018)
Ay Nihat, MPI for Mathematics, Leipzig, Germany (April–May 2019)

Bach Brigitte, AIT Austrian Institute of Technology (Dec 2016)
Bail Christopher, Duke University, USA (Sept 2018)
Baker Chris, University of Queensland, Australia (May–June 2018)
Balázs Lengyel, Hungarian Academy of Sciences ANET-LAB, Budapest, Hungary (Nov 2019)
Bard Jonathan, University of Oxford, UK (Nov 2016)
Barton C. Michael, Arizona State University, USA (April 2019)
Barzel Baruch, Bar-Ilan University, Israel (June 2018)
Bast Gerald, University of Applied Arts Vienna, Austria (Nov 2016)
Bathiany Sebastian, Wageningen University, Netherlands (June 2016)
Baudot Pierre, Max Planck Institute for Mathematics in the Sciences and Complex System Institute ISC-PIF, Germany (Nov 2019)
Beck Christian, Queen Mary College London, UK (April–May 2019)
Becker Sophia, IASS Potsdam, Germany (Sept 2019)
Beklaryan Armen, NRU Higher School of Economics, Moscow, Russia (July 2018)
Bennett Jim, University of Washington, USA (Oct 2019)
Benson Mikael, Linköping University, Sweden (Oct 2016)
Bianchi Cesare, Software Architect, Rome, Italy (Feb 2017, March 2017)
Bianconi Ginestra, Queen Mary University, London, UK (Nov 2019)
Bizjak Klemen, Maribor City Municipality, Slovenia (May 2018, Sept 2018)
Blakely Sandra, Emory University, USA (June 2017)
Blaž Golob, SmartCityPlatform, Slovenia (May 2018)
Boguna Marian, University of Barcelona, Spain (Nov 2019)
Bokányi Eszter, Eötvös-Loránd University, Budapest, Hungary (Feb 2019, March 2019)
Bombari Simone, Scuola Normale Superiore di Pisa, Italy (June–July 2018)
Borsos András, Central European University, Budapest, Hungary (Sept 2017, Aug–Sept 2020)
Bourgine Paul, French National Center for Scientific Research, Paris, France (May 2016)
Boyd Ryan, University of Texas at Austin, USA (March 2018)
Brands Rudi, Nanyang Technological University Singapore (June 2016)
Brody Dorje, Surrey University, UK (April–May 2019)
Brunnengräber Achim, Freie Universität Berlin, Germany (March 2018)
Burkholz Rebekka, ETH Zurich, Switzerland (June 2018)
Bützer Michael, Cleantech 21, Zurich, Switzerland (May 2018, Sept 2018)

Cagnilia Guido, Konrad Lorenz Institute KLI, Austria (Sept 2019)
Caldarelli Guido, IMT Institute for Advanced Studies, Italy (May 2016)
Carlowitz Tom, TU Dresden, Germany (Sept–Nov 2018)
Carreño-Chasin Cesar, ICLEI Bonn, Germany (Sept 2018)
Casiraghi Giona, ETH Zurich, Switzerland (June 2018)
Cebrian Manuel, MIT Media Lab, USA (Sept 2018)
Centeno Miguel, Princeton University, USA (Oct 2019, Nov 2019)
Chapuis Bertil, University of Lausanne, Switzerland (Dec 2019)
Chiara Giovanna, Rodi ISI Foundation, Torino, Italy (Feb 2016)
Chontorozea Tatiana, Medical University of Vienna, Adameyko Lab, Austria (Feb 2019)
Chung Karen, Nanyang Technological University Singapore (June 2017)
Colon Célian, IIASA, Austria (Oct 2019)
Conor Heins, Max Planck Institute for Ornithology, Konstanz, Germany (March 2018)
Corominas-Murtra Bernat, IST Austria (Nov 2019)
Corral Álvaro, Centre de Recerca Mathematica Barcelona, Spain (May 2018, Nov 2019)
Couzin Iain, Max Planck Institute Konstanz, Germany (Sept 2018)
Cox Geraldine, Imperial College London, UK (Sept 2018)
Crampe Lara, Pure Earth, USA (June 2018)
Cremades Roger, Climate Service Center Germany (Sept 2019)
Csermely Peter, Semmelweis University Budapest, Hungary (May 2016)

Dakos Vasilis, University of Montpellier, France (June 2018)
Dankulov Marija Mitrovic, Institute of Physics, Belgrade, Serbia (May 2018, Nov 2019)
Danos Vincent, CNRS Paris, France (Feb 2017)
Dapp Marcus, FuturICT 2.0, ETH Zurich, Switzerland (Sept 2018)
de Arcangelis Lucilla, University of Campania "Luigi Vanvitelli", Italy (Sept 2018)
De Bacco Caterina, Santa Fe Institute, USA (Feb 2017)
DeDeo Simon, Carnegie Mellon University, USA (May 2016)
Deguchi Hiroshi, Tokyo Institute of Technology, Japan (Nov 2017)
del Rio Chanona R. Maria, University of Oxford, UK (Dec 2019)
Diaz-Guilera Albert, Universitat de Barcelona, Spain (May 2016)
Dichand Eva, University Council of the MedUni Vienna, Austria (Dec 2018)
Dieckmann Ulf, IIASA, Austria (Nov 2018, Sept 2018)
Dignum Virginia, Delft University of Technology, Netherlands (May 2017)
Di Matteo Tiziana, King's College London, UK (May 2016, May 2018)
Doblhoff-Dier Otto, University of Veterinary Medicine, Austria (Oct 2019)
Draper Jack, Princeton University, USA (June–Aug 2018)
Dubbeldam Johan, Delft University of Technology, Netherlands (Dec 2018, Feb 2019)
Duran-Frigola Miquel, IRB Barcelona, Spain (Oct 2016)

Edelmann Achim, University of Bern, Switzerland (Feb 2020)
Ederer Brigitte, Infineon Technologies Austria (Dec 2016)
Eibl Gregor, Danube University Krems, Austria (Sept 2018)
Eker Sibel, IIASA, Austria (May 2019)
Escobar Farfán Luis O. L., Banco de Mexico, Mexico (Feb–March 2019)

Fabianek Christoph, TU Wien, Austria (Sept 2018)
Falivene Elisabetta, Sapienza University of Rome, Italy (Feb 2017, March 2017, July 2019)
Faulhammer Friedrich, Danube University Krems, Austria (Jan 2018)
Faure Louis, Medical University of Vienna, Center for Brain Research, Austria (Feb 2019)
Ferres Leo, Universidad del Desarrollo, Chile (Dec 2019)
Ferscha Alois, Johannes Kepler University Linz, Austria (May 2017)
Fineder Martina, Institute of Design Research Vienna, Austria (Feb 2017, March 2017)
Fischer Michael, Danube University Krems, Austria (July 2019)
Flamm Christoph, University of Vienna, Austria (May 2016)
Flöck Fabian, GESIS – Leibniz-Institute for the Social Sciences, Germany (Jan 2019)
Flores-Tames Erwin, Banco de Mexico, Mexico (Feb 2019)
Forrest Stephanie, University of New Mexico, USA (Oct 2019)
Fugiglando Umberto, MIT, USA (May 2018)

Gadotti Andrea, Imperial College London, UK (Dec 2019)
Galaz Victor, Stockholm Resilience Centre, Sweden (Jan 2020)
Galesic Mirta, Santa Fe Institute, USA (Dec 2018, Oct 2019)
Gara Stefan, Vienna Municipal Council, Austria (Dec 2020)
Garlanda Lisa, SONY CSL Paris, France (Feb 2019)
Garlaschelli Diego, Leiden University, Netherlands (April–May 2019)
Gastner Michael, Yale–NUS College, Singapore (Dec 2017)
Gauvin Laetitia, ISI Foundation, Italy (Dec 2019)
Gavrilets Sergey, University of Tennessee, USA (Oct 2019)
Gebetsroither-Geringer Ernst, AIT Austrian Institute of Technology (Dec 2016)
Gelfand Michele, University of Maryland College Park, USA (Oct 2019)
Gellert Alexandre, UNFCCC Paris, France (Sept 2018)
Gerschberger Markus, FH Upper Austria (Oct 2018)
Gessner Mark, TU Berlin, Germany (June 2018)
Gewessler Leonore, Federal Minister for Climate Action, Environment, Energy, Mobility, Innovation and Technology (March 2021)
Gili Tommaso, IMT Institute for Advanced Studies Lucca, Italy (June 2017)
Gingrich Simone, University of Natural Resources and Life Sciences, Austria (Sept 2019)
Gleta Filip, Barclays Investment Bank, London, UK (July 2020)
Goméz-Cabrero David, Karolinska Institutet, Sweden (Oct 2016)
Goméz-Ramiréz Danny Arlen de Jesús, ITM – Instituto Tecnológico Metropolitano, Colombia (Aug 2018)
Gorski Piotr, Warsaw University of Technology, Poland (Sept 2020)
Grabic Roman, South Bohemian University, Czech Republic (July–Aug 2018)
Graser Anita, AIT Austrian Institute of Technology (Dec 2019)
Gratzer Georg, University of Natural Resources and Life Sciences, Austria (June 2018)
Gravino Pietro, Sapienza University of Rome, Italy (March 2017)
Gronenborn Detlef, Johannes Gutenberg University Mainz, Germany (Oct 2019)
Gründl Harald, Institute of Design Research Vienna, Austria (Feb 2017, Sept 2018)
Guerin Stephen, Simtable LLC, Santa Fe, USA (May 2016)
Guth Stefan, Eberhard-Karls-Universität Tübingen, Germany (June 2018)

Häupl Michael, WWTF, Austria (Feb 2021)
Hadzikadic Mirsad, University of North Carolina at Charlotte, USA (March 2020)
Hampl Erich, B&C Foundation, Austria (Jan 2020)
Hanebeck Jochen, Infineon Technologies Austria (Dec 2016)
Haslhofer Bernhard, AIT Austrian Institute of Technology (Dec 2016)
Hauser Hermann, Hauser Investment, Vienna, Austria (Oct 2017)
Havlin Shlomo, Bar-Ilan University, Israel (Dec 2017)
Heinrich Torsten, University of Oxford, UK (Jan 2019)
Helbing Dirk, ETH Zurich, Switzerland (Jan 2017, Feb 2017, May 2017, May 2018, Sept 2018)
Hemmelmayr Vera, Austria (Oct 2019)
Henzinger Tom, IST Austria (Feb 2018)
Herberg Jeremias, Leuphana University, Germany (Sept 2019)
Herlitschka Sabine, Infineon Technologies Austria (Dec 2016)
Hochfilzer Leonhard, Oxford University, UK (Aug 2017)
Hogan John, University of Bristol, UK (Nov 2016, Oct 2019)
Hogeweg Paulien, University of Utrecht (Nov 2016)
Hołyst Janusz, Warsaw University of Technology, Poland (Feb 2018)
Hordijk Wim, Konrad Lorenz Institute KLI, Austria (May 2016, Nov 2016)
Hoyer Dan, The Evolution Institute, San Antonio, USA (Oct 2019)

Ilić Velimir, Serbian Academy of Sciences and Art, Serbia (Oct 2017, April 2019)
Iniguez Gerardo, Central European University, Budapest, Hungary (April 2019)

Jacak Jaroslaw, FH Oberösterreich, Austria (July 2019)
Jackson Joshua Conrad, University of North Carolina, Chapel Hill, USA (Oct 2019)
Jafari G. Reza, Central European University, Budapest, Hungary (Nov 2019)
Jäger Carlo, Global Climate Forum, Berlin, Germany (Sept 2019)
Jäger Johannes, Konrad Lorenz Institute KLI, Austria (Nov 2016)
Jain Sanjay, University of Delhi, India (Nov 2017)
Janischewski Anja, University of Bielefeld, Germany (Sept 2020)
Jasanoff Sheila, Harvard Kennedy School, USA (April 2018)
Jensen Henrik, Imperial College London, UK (May 2016, May 2018, Sept 2018)
Jizba Petr, Czech Technical University in Prague, Czech Republic (Jan 2018, July 2018, April 2019)
Jouda Qusai, FuturICT 2.0, ETH Zurich, Switzerland (May 2018, Sept 2018)
Józwiak Ákos, Nébih, Budapest, Hungary (Feb 2019)
Juntong Prajin, Deputy Prime Minister of Thailand, & Delegation (April 2019)

Kalayil Jose Jacob, Bangalore India Advantage Summit, India (May 2018, Sept 2018)
Kanhere Salil, School of Computer Science and Engineering at UNSW Sydney, Australia (April 2018)
Karimi Fariba, GESIS, Germany (Feb 2020)
Kaski Kimmo, Aalto University School of Science, Finland (May 2017, Oct 2017, Jan 2018, May 2018)
Kauffman Stuart, The Institute for Systems Biology, Seattle, USA (May 2016)
Kaup-Hasler Veronica, Executive City Councilor for Cultural Affairs and Science, City of Vienna (Nov 2019)
Kenett Yoed, University of Pennsylvania, USA (Jan 2020)
Kerchof Carolyn, FuturICT 2.0, ETH Zurich, Switzerland (Sept 2018)
Kertész János, Central European University Budapest, Hungary (April 2016, March 2017, Aug 2020)
Khraisha Tamer, Central European University, Budapest, Hungary (Sept–Nov 2017)
King Ross, AIT Austrian Institute of Technology (Dec 2016)
Kirchner Stefan, Zhejiang University, Hangzhou, China (July–Aug 2018)
Klaffenböck Manfred, TU Wien, Austria (Nov 2018, July 2019)
Klauser Stefan, ETH Zurich, Switzerland (May 2018, Sept 2018)
Klein Brennan, Northeastern University, USA (March 2018)

Kleineberg Kaj-Kolja, ETH Zurich, Switzerland (May 2017)
Knoblich Jürgen, IMBA, Austria (April 2019)
Köhler Sebastian, Charité Berlin, Germany (Oct 2016)
Kolchinsky Artemy, Santa Fe Institute, USA (April 2017, Jan 2018)
Kondor Imre, Parmenides Foundation, Budapest (May 2016, Nov 2016, Sept 2017, May 2018, Jan–Feb 2019)
König Philip, Greater Geneva 4 Global Goals, Switzerland (May 2018)
König Reinhard, AIT Austrian Institute of Technology (Dec 2016)
Krakauer David, Santa Fe Institute, USA (May 2016, Oct 2018, Oct 2019)
Kreuzbauer Robert, Nanyang Technological University Singapore (June 2016)
Krieglstein Stefan, Krieglstein & Company, Vienna, Austria (Oct 2018)
Kristoferitsch Lotte, Institute for Design Research Vienna, Austria (March 2017)
Kristoufek Ladislav, Charles University Prague, Czech Republic (Oct 2018)
Kühn Christian, Technical University of Munich, Germany (May 2018)
Kunsic Nina, Semmelweis University, Budapest, Hungary (Feb 2019)

Lahlou Saadi, London School of Economics and Political Science, UK (Oct 2017, Oct 2018, Oct 2019)
Lambiotte Renaud, University of Namur, Belgium (May 2016)
Lampoltshammer Thomas, Danube University Krems, Austria (Sept 2018)
Lang Daniel, Leuphana University, Germany (Sept 2019)
Lansing J. Stephen, Nanyang Technological University Singapore / Santa Fe Institute, USA (May 2016, Sept–Oct 2016, June–July 2017, Aug 2018, Aug–Nov 2019)
Latora Vito, Queen Mary University of London, UK (May 2016, May 2018, March 2019)
Laubichler Manfred, Arizona State University, USA (May 2016, Nov 2016, May 2018, Oct 2018, Sept 2019, Oct 2019)
Lehmann Heiko, Telekom Innovation Laboratories, Berlin, Germany (Dec 2019)
Leonhardt Ulf, Weizmann-Institute, Israel (Aug 2018)
Lepperdinger Günter, Paris-Lodron-University of Salzburg, Austria (Sept 2016)
Lerman Kristina, University of Southern California, USA (March 2019)
Letina Srebrenka, Central European University Budapest, Hungary (Jan 2019)
Levin Simon, Princeton University, USA (Oct 2017, Oct 2018, Oct 2019)
Lingner Claudia, Ludwig Boltzmann Society, Austria (May 2017)
Loibl Wolfgang, AIT Austrian Institute of Technology (Dec 2016)
Lonhus Kirill, South Bohemian University, Czech Republic (July 2018, July 2019)
Lukovicz Paul, Technical University Kaiserslautern, Germany (May 2017)

Maag Balz, ETH Zurich, Switzerland (Aug 2018)
Mahrer Harald, Austrian Economic Chambers (Feb 2018)
Malik Lukas, University of Vienna, Austria (April 2019)
Manrubia Susanna, Spanish National Centre for Biotechnology CSIC, Spain (Sept 2018)
Mantegna Rosario, Palermo University, Italy (May 2016, May 2018, May–June 2019)
Marquardt Wolfgang, Forschungszentrum Jülich, Germany (Sept 2016)
Marsili Matteo, ICTP Trieste, Italy (Nov 2019)
Mastrandrea Rossana, IMT Institute for Advanced Studies Lucca, Italy (June 2017)
Matei Liviu, Central European University Budapest, Hungary (Oct 2019)
Matusuzoe Hiroshi, Nagoya Institute of Technology, Japan (June 2019)
Mayer Katja, University of Vienna, Austria (Dec 2019)
Medda Francesca, UCL – London's Global University, QASER-LAB, UK (Sept 2018)
Mei-Pochtler Antonella, Think Austria, Austrian Federal Chancellery (Oct 2018)
Menche Jörg, Research Center for Molecular Medicine CeMM, Austria (Oct 2016, Feb 2019)
Menczer Filippo, Indiana University, USA (Jan 2018)
Mendes José Fernando, University of Aveiro, Portugal (May 2018)
Meran-Waldstein Isabella, Federation of Austrian Industries IV (April 2018)
Michalski Radoslaw, Wrocław University of Science and Technology, Poland (June 2018)
Milton Helena, Central European University Budapest, Hungary (Oct 2019)
Mondardini Rosy, University of Zurich, Switzerland (Sept 2018)
Monica Stefania, Università degli Studi di Parma, Italy (March 2018)
Morán José, École Polytechnique Paris, France (Feb 2019)
Moreno Yamir, University of Zaragoza, Spain (May 2016, Jan–Feb 2018)
Mühlmann Pamela, Urban Innovation Vienna, Austria (Sept 2018)
Müllneritsch Robert, Infineon Technologies Austria (Dec 2016)
Mutlu Belgin, Know Center, Graz, Austria (Nov 2018)

Nanetti Andrea, Nanyang Technological University Singapore (June 2017, Sept 2018)
Naudts Jan, University of Antwerp, Netherlands (Jan 2018, April 2019)
Nax Heinrich, ETH Zurich, Switzerland (May 2017)
Neffke Frank, Harvard Kennedy School, USA (Oct 2019, Feb 2020)
Neidhardt Julya, TU Wien, Austria (June 2018)
Neuper Christa, University of Graz, Austria (Feb 2016)
Niess Marie-Therese, Member of the Austrian Parliament (Oct 2018)
Nordbotten Jan, University of Bergen, Norway (Oct 2017)
Novakovic Tatjana, Vienna University of Economics, Austria (Sept 2018)

Oksanen Atte, University of Turku, Finland (Aug 2019)
Olsson Henrik, Santa Fe Institute, USA (Dec 2018, Oct 2019)
Osten Olaf, artist, Vienna, Austria (Sept 2018)

Palchykov Vasyl, The National Academy of Sciences of Ukraine (Jan 2018, Jan 2021)
Paluch Robert, Warsaw University of Technology, Poland (July–Sept 2020)
Palus Milan, Academy of Sciences of the Czech Republic (April 2018)
Paradowski Michal, University of Warsaw, Poland (Sept 2018)
Perc Matjaz, Complex Systems Center Maribor, University of Maribor, Slovenia (May 2016, Nov 2019)
Pereira Carlos Alvarez, Club of Rome, Italy (Sept 2019)
Petri Giovanni, ISI Foundation, Italy (Nov 2019)
Pfeiffer Ruth, National Cancer Institute (NIH), USA (May 2019)
Pfenninger Stefan, ETH Zurich, Switzerland (June 2018)
Pichler Anton, University of Oxford, UK (June 2017, April 2018, July–Sept 2019)
Pichler Rupert, Federal Ministry for Transport, Innovation and Technology, Austria (March 2018)
Pietronero Luciano, Sapienza University of Rome, Italy (May 2016, May 2018)
Pignolet Yvonne-Anne, Dfinity Foundation, Zurich, Switzerland (Nov 2019)
Pineda Carlos, Central European University Budapest, Hungary (July 2018, April 2019)
Ploss Reinhard, Infineon Technologies Austria (Dec 2016)
Poellabauer Christian, University of Notre Dame, USA (May 2019)
Polz Martin, University of Vienna, Austria (Oct 2019)
Polzer Miroslav, International Association for the Advancement of Innovative Approaches to Global Challenges IAAI, Klagenfurt, Austria (Nov 2019)
Pournaras Evangelos, ETH Zurich, Switzerland (May 2017)
Preiser Rilka, Stellenbosch University, South Africa (Sept 2019)
Preiser-Kapeller Johannes, Austrian Academy of Sciences, Austria (Oct 2017, March 2019)
Proks Martin, Czech Technical University in Prague, Czech Republic (Dec 2018)
Przulj Natasa, University College London, UK (Oct 2016)

Rade Luca, Princeton University, UK (June 2017, May 2018)
Rahwan Iyad, MIT Media Lab, UK (Sept 2018)
Rapisarda Andrea, University of Catania, Italy (May 2018, Nov 2019)
Rauskala Iris, Austrian Ministry of Education, Science and Research, Austria (Jan 2020)
Rauter Harald, Climate-KIC, Munich, Germany (Sept 2018)
Rehman Semeen, TU Wien, Austria (Oct 2018)
Rezagholi Sharwin, Max Planck Institute for Mathematics in the Sciences, Leipzig, Germany (March 2018)
Riede Felix, Aarhus University, Denmark (June 2018)
Rimé Bernard, Catholic University of Leuven, Belgium (March 2019)
Ringsmuth Andrew, Stockholm Resilience Centre, Sweden (May 2018, Nov 2019)
Rodrigues Francisco, Universidade de Sào Paulo, Brazil (Oct 2018)
Roller Ramona, ETH Zurich, Switzerland (June 2018)
Rovenskaya Elena, IIASA, Austria (Sept 2018)

Saakian David, Yerevan Physics Institute, Armenia (Nov 2019)
Saavedra Serguei, MIT, USA (June 2018)
Safarzynska Karolina, University of Warsaw, Poland (June 2018)

Sakr Sherif, King Saud bin Abdulaziz University for Health Sciences, Saudi Arabia (Aug 2017)
San Miguel Maxi, IFISC Palma de Mallorca, University of the Balearic Islands, Spain (May 2016, May 2018)
Sattler Michael, City of Vienna, Austria (May 2018, Sept 2018)
Saurugg Herbert, Cyber Security Austria (May 2017, Sept 2018)
Schaal Gary, Helmut Schmidt University, Germany (Sept 2018)
Schädler Ingolf, Federal Ministry for Transport, Innovation and Technology, Austria (Nov 2018)
Schifanella Rossano, University of Turin, Italy (Dec 2019)
Schläpfer Markus, ETH Future Cities Laboratory, Switzerland (May 2016)
Schlögl Lukas, University of Vienna, Austria (Dec 2019)
Schlüter Maja, Stockholm Resilience Center, Sweden (Sept 2019)
Schmid Martin, University of Natural Resources and Life Sciences, Austria (June 2018)
Schmid Sonja, Virginia Tech, USA (June 2018)
Schmid Stefan, University of Vienna, Austria (Dec 2019)
Schmieg Gregor, Leuphana University, Germany (Sept 2019)
Schmitt Gerhard, ETH Zurich, Switzerland (May 2016, Nov 2016, Oct 2018, Oct 2019)
Schneider Georg, IST Austria (Feb 2018)
Scholtes Ingo, ETH Zurich, Switzerland (Sept 2018)
Schrickel Isabell, Leuphana University, Germany (Sept 2019)
Schuster Peter, University of Vienna, Austria (May 2016)
Schweighofer Simon, ETH Zurich, Switzerland (March 2018)
Schweitzer Frank, ETH Zurich, Switzerland (May 2016, May 2018, June 2018)
Schweizer Pia, IASS Potsdam, Germany (Sept 2019)
Selomane Odirilwe, Stockholm Resilience Centre, Sweden (June 2018)
Serdult Uwe, University of Zurich, Switzerland (March 2019)
Shutters Shade, Arizona State University, USA (June 2019)
Simlinger Florentina, University of Vienna, Austria (Sept 2018)
Sinatra Roberta, Central European University, Budapest, Hungary (Jan 2018, May 2018, March 2019)
Sloot Peter M.A., Institute of Advanced Studies Amsterdam, Netherlands (May 2016, Nov 2016, May 2017, May 2018)
Smirnov Ivan, National Research University Higher School of Economics, Moscow, Russia (April, 2017, Aug 2018, Feb 2020)
Sneppen Kim, University of Copenhagen, Denmark (May 2016)
Solé Ricard, Universitat Pompeu Fabra, Spain (May 2018, March 2019)
Sorensen Vibeke, Nanyang Technological University Singapore (Aug 2019)
Spinney Laura, freelance journalist, USA (Oct 2019)
Stadtfeld Christoph, ETH Zurich, Switzerland (May 2019)
Stamatescu Grigore, University Politehnica of Bucharest, Romania (Feb–Aug 2019)
Stenseth Nils Christian, University of Oslo, Norway (Oct–Nov 2017)
Strasberg Philipp, Autonomous University of Barcelona, Spain (May 2020)
Stys Dalibor, South Bohemian University, Czech Republic (March 2016, July–Aug 2018, July 2019)
Stysová Rychtáriková Renata, South Bohemian University, Czech Republic (July 2019)
Suyari Hiroki, Chiba University, Japan (April 2019)
Szathmáry Eörs, Eötvös-Loránd University, Hungary (Oct 2017, March 2019)
Szell Michael, Central European University Budapest, Hungary (May 2018)

Tacchella Andrea, Sapienza University of Rome, Italy (Jan 2020)
Taddei François, Center for Research and Interdisciplinarity Paris, France (Oct 2016)
Tadic Bosiljka, Jozef Stefan Institute, Slovenia (May 2016, May 2018, Nov 2019)
Takao Terano, Tokyo Institute of Technology, Japan (Nov 2017)
Tatonetti Nicholas, Columbia University, USA (Oct 2016)
Taudes Alfred, Vienna University of Economics and Business, Austria (Dec 2016)
Teixeira dos Santos Tiago, Graz Technical University, Austria (Dec 2019)
Themann Dörte, Freie Universität Berlin, Germany (June 2018)
Thiyageswaran Vydhourie, Princeton University, USA (June 2019)
Thomas Tobias, EcoAustria (March 2020)
Tockner Klement, Austrian Science Fund, Austria (Jan 2017)
Trappl Robert, OFAI Austrian Research Institute for Artificial Intelligence, Austria (Sept 2018, Dec 2018)
Tria Francesca, Sapienza University of Rome, Italy (Feb 2016, May 2018)
Trpin Borut, University of Salzburg, Austria (April 2019)
Tsallis Constantino, Centro Brasileiro de Pesquisas Fisicas, Rio de Janeiro, Brazil (May 2017, May–June 2018, March 2019, April–May 2019)
Turchin Peter, University of Connecticut, USA (Sept–Oct 2017, Sept–Oct 2018)

Valdano Eugenio, Universitat Rovira i Virgili, Spain (May 2017)
van de Leemput Ingrid, Wageningen University, Netherlands (June 2018)
van den Hoven Jeroen, Delft University of Technology, Netherlands (May 2017)
van der Leeuw Sander, Arizona State University, USA (May 2017, Oct 2017, Sept 2019)
Van der Bellen Alexander, Austrian Federal President, Austria (June 2020)
Vanhoof Maarten, Newcastle University, UK (April 2018)
Vasbinder Jan, Nanyang Technological University Singapore (May 2016, Dec 2016, April 2017, June 2017)
Vatta Gabor, Eötvös-Loránd University Budapest, Hungary (May 2016)
Veres Daniel, Semmelweis University Budapest, Hungary (May 2016)

Wagner Fabian, IIASA, Austria (Sept 2018, Dec 2019)
Wazir Rania, Vienna Data Science Group, Austria (Dec 2019)
Weinstock Michael, Architectural Association Austria (Sept 2018)
Weitgruber Barbara, Federal Ministry of Education, Science and Research, Austria (June 2018)
Wendtner Sabine, Climate Alliance Lower Austria (Sept 2018)
Wenyuan Liu, Nanyang Technological University Singapore (May 2018)
West Geoffrey, Santa Fe Institute, USA (Jan 2018, May 2018)
Widder Stefanie, Medical University of Vienna, Austria (May 2016, Feb 2019)
Wiedenhofer Dominik, University of Natural Resources and Life Sciences, Austria (Sept 2019)
Wiesmüller Michael, Federal Ministry for Transport, Innovation and Technology, Austria (March 2019)
Wiesner Karoline, University of Bristol, UK (May 2016, Jan 2018, May 2018)
Wiestler Othmar, Helmholtz Society, Germany (Feb 2017)
Wilk Grzegorz, National Centre for Nuclear Research, Warsaw, Poland (April 2019)
Winiwarter Verena, University of Natural Resources and Life Sciences, Austria (March–Sept 2019)
Wirtz Kai, Helmholtz-Zentrum Geesthacht, Germany (Oct 2019)
Wolpert David, Santa Fe Institute, USA (April 2017, April–May 2019, Feb 2020)

Yasseri Taha, Oxford Internet Institute, UK (Jan–Feb 2018)
Youn Hyejin, Oxford University, UK (May 2016)

Zatloukal Václav, Czech Technical University in Prague, Czech Republic (May 2019)
Zlatic Vinko, Institut Ruđer Bošković, Croatia (Jan 2018)
Zych Izabela, University of Cordoba, Spain (Aug 2019)

The Hub Goes Pub lic

The motto of all CSH outreach activities is: Do good research—and talk about it!

As the person in charge, I dare to say: The Hub can be proud of its outreach. When it comes to media attention, for instance, the first years showed a steady increase of CSH-related mentions in national as well as international media, including prestigious outlets like the *New York Times*, the BBC, *The Economist, Bloomberg News, The Guardian, Nature News, FAZ, Der Spiegel, Die Zeit, El País, The Times*, and so many more.

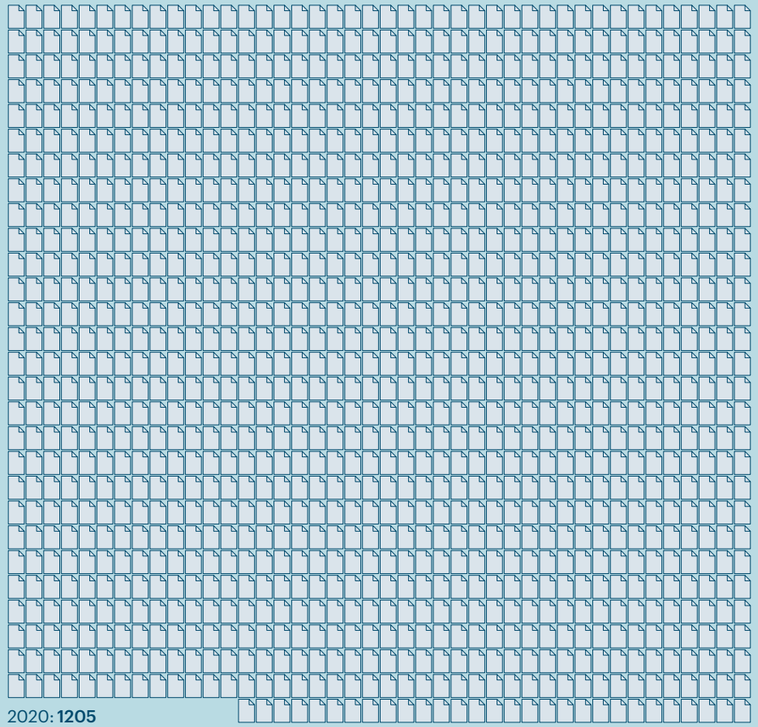
While things had already started off quite well, corona placed a huge media spotlight on the Hub. As part of the prognostic consortium advising the Austrian Health Ministry on COVID-19 infection trends, Hub researchers and Hub research became regular guests and topics on Austrian TV and radio stations and were featured online and in print media. Furthermore, our COVID-related findings and prognoses were picked up and broadly discussed internationally. In the first four months of 2021 alone, we counted as many press appearances as in all of 2020; and as of May 2021, the big wave has not yet crested…

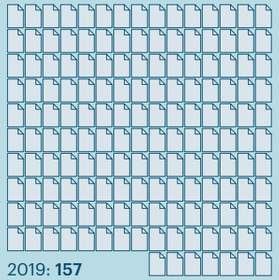
Apart from its media work, the CSH "knowledge transfer & dissemination" activities focus on public events organized or co-organized by the Hub. Turn the pages to find the public conferences and colloquia, as well as the Art & Science at the Hub events that took place between May 2016 and May 2021.

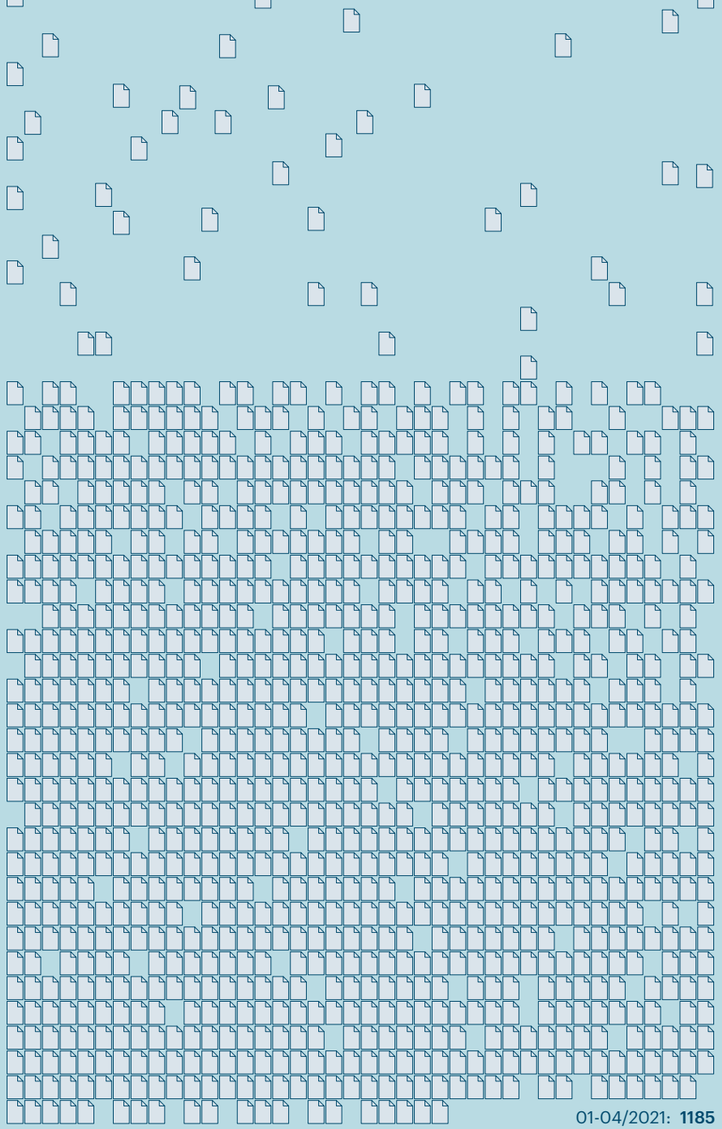
LOOKING INTO THE FUTURE

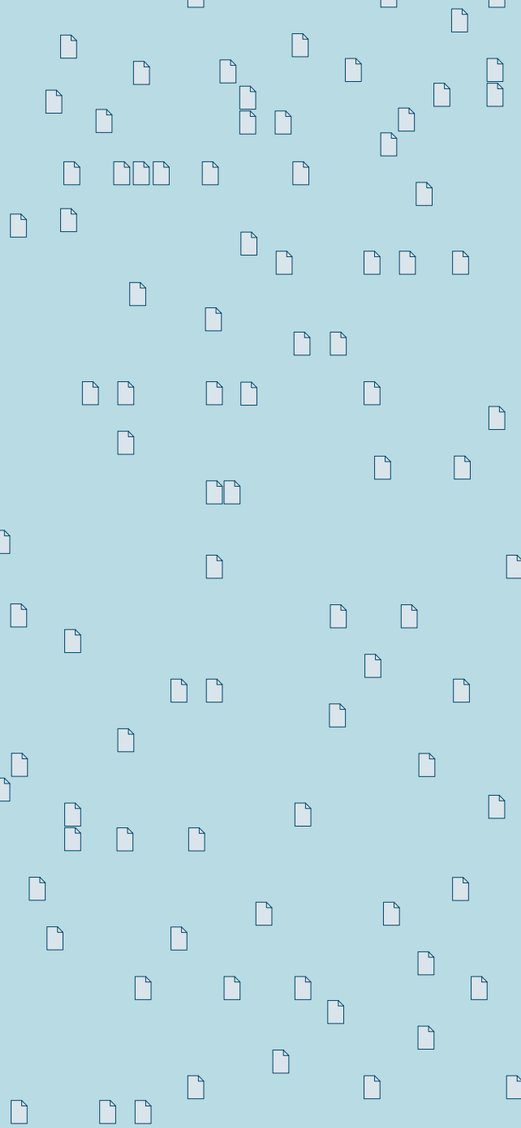
The Hub is growing, and so are our press and outreach activities. Since our early days, outreach work has multiplied; and with the new people and research fields starting at the Hub, it will certainly not become less in upcoming years.

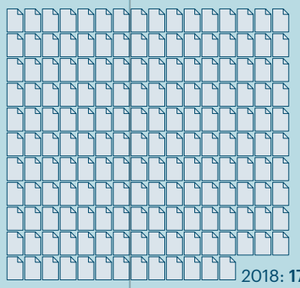
We therefore decided to double our knowledge transfer team—from one woman to two people—within the year: to reach out even further, to new interest groups and media, with new formats and science communication events. Always according to our motto: Do great research—and talk about it.











The Hub in the media. The first years showed a steady increase of CSH-related mentions in national and international media. From January to May 2021, our researchers had more media appearances than in the whole—already very busy—corona year 2020.

Public Conferences

Well-known complexity scientists often travel from afar to Vienna to take part in our workshops and scientific meetings. With our public lectures, conferences, and colloquia, we take advantage of their stay and let them present the newest findings, insights, or discuss pressing questions with an interested audience.

Talks marked with this icon were recorded and can be seen on our YouTube channel.

May 23, 2016
CSH Opening Conference

Visions for Complexity

This was the official start of the Hub: On May 23, 2016 we inaugurated the CSH—and at the same time its new location in the beautiful baroque Palais Strozzi in downtown Vienna—with the conference "Visions for Complexity."
At this meeting, a Who's Who of 35 internationally acclaimed scientists shared their visions for complexity science in the next decade. How can complexity science and Big Data science help society tackle some of the grand challenges that lay ahead of us? How can the new "Hub" in Vienna be a beneficial facilitator on this path? The visions were assembled and published in a book called *43 Visions for Complexity* (2017). They serve as kind of a roadmap for the next decade of complex systems research at the Hub.

Aug 25, 2016
CSH @ Alpbach Technology Symposium

Complexity and the New Enlightenment

Humanity is increasingly interconnected, and the planet is becoming ever harder to maintain as a stable place for our species. Increased complexity offers both tremendous potential and threat to our survival. Does this mean that we are heading for a new era of self-inflicted immaturity?
In a panel discussion, organized and chaired by CSH President Stefan Thurner, three international complexity scientists discussed whether science could offer strategies to avoid new dangers and what science can contribute to the New Enlightenment.
The panelists were Albert-László Barabasi (Northeastern University, Boston, MA), Dirk Helbing (ETH Zurich & CSH External Faculty), and Roberta Sinatra (Central European University, Budapest & CSH External Faculty).

Sept 19–22, 2016
CSH in Amsterdam

Conference on Complex Systems

Since 2004, the Conference on Complex Systems (CCS) has been one of the most important annual meetings for the complex systems research community. In 2016, the CCS took place in Amsterdam. From that time onward, the CSH has been a cooperation partner of this interdisciplinary scientific gathering.

Sept 21, 2016

Santa Fe Workshop @ CCS 2016

This workshop, organized by CSH President Stefan Thurner, Geoffrey West (Santa Fe Institute & CSH External Faculty), and J. Stephen Lansing (Nanyang Technological University Singapore & CSH External Faculty), took place within the framework of the Conference on Complex Systems 2016 in Amsterdam. Scientists associated with the SFI presented their views, opinions, and concepts to make progress in understanding complex systems. The workshop was inspired by the style of one held at the SFI: open, highly interactive, and intellectually stimulating.

Oct 26–31, 2016
CSH Partner of the Kreyon Days 2016

Creativity and Innovation Dynamics

Kreyon is a research project investigating the dynamics of creativity and innovation. It aims to promote interactive engagement with science by playing experimental online games.
The Kreyon Days 2016, organized by project coordinator Vittorio Loreto from the CSH, took place as a live event in Rome. It fostered an interactive engagement in science with the public. The CSH was a proud partner of this event.

May 9, 2017
CSH Public Colloquium

Re-inventing Society in the Digital Age

The digital revolution will leave no one untouched. Digital technologies will fundamentally change the area of services and product portfolios. Entire business models and economic sectors, institutions and even our living together as a society will change—completely new ecosystems will emerge. But how exactly might this digital future look? How do we want our future society to be, and how will we get there?
The colloquium followed a scientific workshop of the same name, organized by CSH External Faculty member Dirk Helbing from ETH Zurich. The workshop participants were invited to present their ideas to an interested public.

Aug 26, 2017
CSH @ Alpbach Technology Symposium

Managing Complex Systems

The management of complex systems—ranging from technology, production, transportation, finance and the economy, to healthcare, medicine, and the environment—is one of the most urgent challenges for society, industry, and

government. Essential for any monitoring and control is the capability to merge the understanding of the dynamics of complex systems with big relational data. The panel was organized by the Hub and led by Helga Nowotny (Chair of the CSH Science Advisory Board, Member of the Austrian Council for Research and Technology Development, and Former President of the European Research Council). The participants discussed the tremendous potential as well as the challenges of understanding complex systems for the benefit of society. Speakers included Simon DeDeo (Carnegie Mellon University & CSH External Faculty), Vittorio Loreto (Sapienza University of Rome & CSH), and CSH President Stefan Thurner.

Nov 7, 2017
CSH & AIT @ Berlin Science Week

Complexity Science for Fundamental Urban Challenges

There is evidence that the size of cities significantly affects factors such as health, communication, or the opinion formation of people. How should cities be planned, built, and governed in an intelligent way? How can the immense data streams cities are producing be transformed into useful knowledge that can be used to develop a city in a sustainable, resilient, and resource-friendly manner?
This workshop, organized within the framework of the Berlin Science Week by the Austrian Institute of Technology AIT and the Hub, introduced concepts of complexity and Big Data science to a wider audience. A special focus was placed on challenges arising from urbanization.

Jan 31, 2018
CSH Colloquium

Life, Universe, and Everything— 42 Is the Answer to the Ultimate Question, "What Is the Question?"

"The answer to the ultimate question of Life, the Universe and Everything is 42," Douglas Adams jokingly wrote in his science fiction classic The Hitchhiker's Guide to the Galaxy. The phrase has become more famous than the novel itself. However, the human quest to understand the complexities of Life, the Universe and Everything is not a joke, but rather an everlasting endeavor.
In this public event organized by CSH External Faculty member Kimmo Kaski from Aalto University, Helsinki, three researchers at the frontiers of complexity science discussed findings of their searches:
The great Geoffrey West from the Santa Fe Institute in New Mexico pondered "The future of the planet: life, growth and death in organisms, cities and companies." Roberta Sinatra, a researcher at Central European University in Budapest, marched "Towards a science of success." Filippo Menczer from the Indiana University School of Informatics, Computing, and Engineering shared his insights on "The spread of fake news by social bots."

▶ The talks were recorded and can be seen on our YouTube channel.

May 24, 2018
CSH Public Conference

Complexity—Where Do We Go from Here?

Every year or so, the Hub invites its External Faculty to debate pressing questions in complexity science, to plan future collaborations and joint projects, and to promote mutual relationships.
A day before their scientific meeting in 2018, 31 CSH affiliates presented their visionary ideas in six- to eight-minute talks to the public. The full-day public event was followed by a vernissage and (due to rain rather indoor…) garden party.

▶ The inspiring and easy-to-comprehend talks were recorded and can be seen on our YouTube channel.

June 7, 2018
CSH Colloquium

Improving Resilience in Complex Systems

In this public colloquium, organized by Frank Schweitzer from ETH Zurich, the concept of resilience was presented from three different angles:
Frank Schweitzer, who is also a member of the CSH External Faculty, spoke about "The resilience of social organizations." Odirilwe Selomane from the Stockholm Resilience Centre was "Dancing with the dynamics: Social-ecological systems insights for sustainable development." CSH President Stefan Thurner explained the "Elimination of systemic risk in financial networks."

Aug 24, 2018
CSH @ Alpbach Technology Symposium

Our Digital Future— How Human Will It Be?

"Technology has firmly taken hold of our world, connecting everybody with everyone. AI and machine learning, data science and complexity science, cybersecurity, and automation—they all use algorithms and growing amounts of data in their computer-based models that radically change our lives and world of work. How are we to deal with this without losing confidence in the future? What can and should these disruptive technologies do for us?" (© Alpbach program)
The 2018 complexity panel in Alpbach was chaired by Helga Nowotny (Chair of the CSH Science Advisory Board); the CSH was represented by CSH External Faculty member J. Stephen Lansing.
The panel speakers were Mirta Galesic (Santa Fe Institute & CSH External Faculty), J. Stephen Lansing (Nanyang Technological University Singapore & CSH External Faculty), and Martina Mara (Johannes Kepler University Linz).

Sept 6, 2018
CSH Colloquium

Machine Behavior

Do we need a new discipline that scientifically studies intelligent software and hardware agents not as products of engineering, but as actors that should be empirically analyzed to reveal their behavioral patterns? CSH's David Garcia invited experts to a workshop to discuss this question.
The day before their scientific meeting, three of the well-known experts in the field presented their thoughts about "machine behavior" to the public:
Iyad Rahwan (MIT Media Lab) addressed the topic "From machine behavior to the algorithmic social contract."
Chris Bail (Duke University, USA) reflected on whether "Exposure to opposing views can increase political polarization: Using bots to study political polarization on Twitter."
Iain Couzin (Max Planck Institute at Universität Konstanz) held a lecture "On fish and fascists: How extremist views influence animal and human collective behavior."

▶ The colloquium was recorded. The single talks can be seen on our YouTube channel.

Sept 17, 2018
CSH Conference

The Ginkgo Meeting

From arts to cosmology, from music to complexity: The ambition of the singular "Ginkgo Meeting," organized by CSH External Faculty member Henrik Jensen and Geraldine Cox, both of Imperial College London, was to initiate an interdisciplinary and transdisciplinary exchange with the aim of investigating "true understanding."
A group of curious, talented, and creative individuals from very diverse fields gathered at the Hub for an experiment: What happens when a spectrum of minds is focused on a single, unbounded part of reality? The (randomly) chosen subject was the ginkgo biloba tree.

Nov 5–6, 2018

D4Dairy: Kick-Off Meeting

In June 2018, the Austrian Research Promotion Agency FFG decided to support a project proposal put together by the Austrian Cattle Breeders' Association within the COMET (Competence Centers for Excellent Technologies) framework. COMET is an Austrian science program launched in 2006 to foster cooperation and knowledge transfer between small, medium, and large enterprises, universities, Universities of Applied Sciences, competence centers, and research institutions.
The project with the beautiful acronym D4Dairy ("Digitalization, Data integration, Detection and Decision support in Dairying") connects dozens of partners from agricultural organizations and farmers, through industry and smaller size enterprises, down to various scientific institutions.
The CSH, which is in charge of the data analyses in the project, opened its premises for the D4Dairy Kick-off Meeting.

Nov 7, 2018
CSH, AIT and ETH @ Berlin Science Week

Cyber Security— How to Protect Critical Infrastructure

In a world that allows increasing interconnectivity and constant evolution in digital matters, our IT systems are more than ever at risk. Digital attackers are constantly refining their strategies: threats lurk behind any networked digital device. Cyber security is becoming a major challenge, and a key factor for the success of any institution. But how can we protect critical infrastructure from threats? What measures are already in place? Will possible attacks ever be diminished? Given the huge importance of this issue, the organizers of this workshop, the Austrian Institute of Technology AIT, the CSH and ETH Zurich, set up a panel discussion as part of the 2018 Berlin Science Week to introduce concepts of complexity and Big Data science focusing on cyber security.

May 22, 2019

D4Dairy Annual Meeting

The CSH Vienna, which is one of the project partners in the D4Dairy consortium, hosted the first annual meeting of the COMET project.

Sept 11, 2019
CSH Colloquium

Sustainability—A Complex Challenge

Popular ideas about sustainability are still largely guided by a techno-scientific ideal of control. Hence, limits and difficulties of this ideal have become obvious. Is there a more adequate methodology for a sustainability science? The answer is yes:
Alternatives have emerged, but have yet to gain wider acceptance in the scientific community.
The CSH Colloquium, organized by Manfred Laubichler (Arizona State University, CSH Science Advisory Board & External Faculty), highlighted several approaches to sustainability that move beyond the control paradigm.
Carlo Jäger (Global Climate Forum & CSH External Faculty) looked "Beyond the wrong kind of complexity: Why sustainability requires a major transition in the evolution of global institutions."
Maja Schlüter (Stockholm Resilience Centre) spoke about "Navigating the emergence of collapses and transformations."
J. Stephen Lansing (Santa Fe Institute & CSH External Faculty) gave "Lessons from the ice age—Why the tropics matter."

▶ The talks and the subsequent panel discussion were recorded and can be seen on our YouTube channel.

Dec 11–13, 2019
CSH hosting the

Brainhack Vienna

"These collaborative workshops combine elements of hackathons and unconferences, with a variety of educational activities, to accelerate the adaptation of data science and computational methods in neuroscience. Much of the conference is allocated to open working time during which attendees are encouraged to work together in interdisciplinary teams on projects that utilize computational techniques to solve problems in neuroscience. Periodic unconference sessions provide an opportunity for attendees to share their expertise on topics that become relevant through the course of the event." (©brainhack.org)
Each local event is encouraged to accept participants from diverse backgrounds. The Brainhack Vienna, organized by https://brainhack.org, orbited around the "EvoDevo" theme.

Aug 28, 2020
CSH @ Virtual Alpbach Technology Symposium

Complexity Science— Corona and the Consequences

The COVID-19 pandemic has taken hold of our world. It is far more than a health crisis, affecting societies and economies at their core. Uncertainty is high.
The invited speakers on this virtual complexity panel discussed the consequences of the crisis from different angles, focusing on approaches that could help manage the pandemic and inform policy-makers. Helga Nowotny (Chair of the CSH Science Advisory Board, Member of the Austrian Council for Research and Technology Development Vienna, and Former President of the ERC European Research Council) served as the moderator and discussed "Corona and the consequences" with Vittoria Colizza (INSERM and University of Sorbonne, Paris), Dirk Helbing (ETH Zurich & CSH External Faculty), Stefan Thurner (CSH President), and Ricardo Hausmann (Harvard University, Cambridge, Massachusetts).

March 3, 2021
CSH co-hosting the

Virtual COVID-19 PHSMs Data Coverage Conference—Part II

After a two-day workshop in February (see "CSH Workshops"), where COVID-19 policy trackers had had the opportunity to network, exchange and share key experiences, explore collaboration possibilities and reflect on lessons learned with data collection to respond to future pandemics, the third day (and Part II) of the Virtual COVID-19 Data Coverage Conference was organized as a public event. The aim was to inform journalists, health authorities, funding institutions, and an interested public about takeaways from the workshop and possible future directions of action.
Amélie Desvars-Larrive, a Hub researcher who was in charge of the CSH Covid-19 Control Strategies List (CCCSL) in the past year, co-hosted the event.

Art &Science at the Hub

Since the early days of the Hub, we have been enriching the big, white walls, the stairways and halls of our premises in Palais Strozzi with a variety of paintings, photographs, collages, and sculptures.

The Art at the Hub program—in some cases extended by a scientific lecture to "An Evening with Art & Science at the Hub"—officially started in February 2017.

In our first five years, we had ten artists presenting their work in nine exhibitions curated by Laura Stöger and—in the case of the last exhibition, the opening of which finally had to take place as a virtual event—by Stephanie Bourke-Altmann.

Feb 1, 2017 — The Art

Olaf Osten
43 Visions for Complexity
Book Presentation & Vernissage

At the first evening with Art&Science at the Hub, we presented a book designed by Olaf Osten, a Vienna-based German artist and graphic designer. *43 Visions for Complexity* is a compilation of ideas from leading complexity scientists about the frontiers of the science of complex systems. These visions were collected at the Hub's kick-off conference in May 2016.

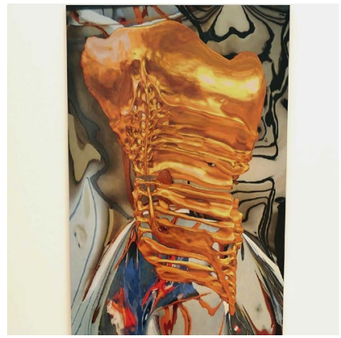
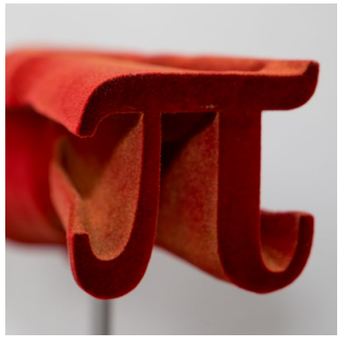
Beside the book, Olaf also showed some of his large-scale paintings and overpaintings.

The Science

Dirk Helbing
The Future of Democracy

In his opening lecture, CSH External Faculty member Dirk Helbing from ETH Zurich asked if democracy actually has a future. While he painted the current situation in rather dark colors, he also came up with ideas to save our institutions, for instance by open science and innovation, a giant shared economy, or the political empowerment of single citizens.

The 25-minute talk was recorded and can be seen on our YouTube channel.



Jan 31, 2018

Uwe B. Sleytr
From Synthetic Biology to Art

Uwe B. Sleytr is an Austrian biotechnologist and artist. He uses mask-like sculptures to visualize the intersection between science and the arts. Sculptures made from clay are plated with leaf gold after firing. "The changes in dimensions symbolize the non-predictable evolution of humans as a consequence of synthetic biology, in particular, genome editing," Uwe says. At the Hub exhibition, he showed large and colorful high-resolution prints of his sculptures.

May 24, 2018

Johann Berger
Word Bodies

The Austrian artist Johann Berger showed his series *Wortkörper ("word bodies")* in the to-date largest Hub exhibition. Johann has a deep connection to the written word and to the pillars of texts: the characters. At the Hub he presented a variety of sculptures derived from ancient Greek and Hebrew characters. While the "word bodies" result from a discourse with Western intellectual history, the technology he uses to show them is strongly rooted in the present. For his amazing pieces, which are sometimes illuminated from the inside by lamps, Johann uses forms of 3D printing, CPI, and laser cutting.

Oct 17, 2018

Christian Bazant-Hegemark
The Beauty of Complexity

The young Austrian artist Christian Bazant-Hegemark is a visual storyteller. He paints open-minded stories whose interpretations grow with their viewers. Christian uses visual fragments to create emotions and narrative strands. In his exhibition at the Hub, he presented works from the years 2011 to 2018.

Feb 21, 2019

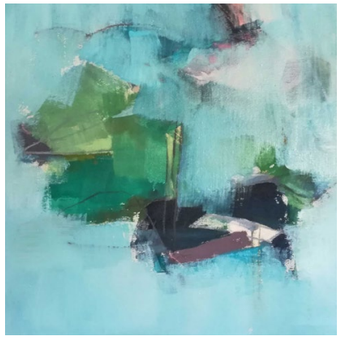
Wendelin Pressl
Angst? Math Helps.

Wendelin Pressl is a truly roguish artist (who feels too pigeonholed if called an “artist”). He aims to disassemble reality into individual particles and to reassemble them in his own individual, intelligent, and very humorous way. His art pieces look like experimental arrangements: The associative (re-)combinations generate reinterpretations and new meanings. An essential part of the concept is always the viewer, who is often invited to interact with the pieces.

May 23, 2019

Roberto Cammi
The Abstraction of Simplicity

The Italian chemist Roberto Cammi exhibited a selection of his black-and-white photographs at the Hub. Roberto’s preferred subjects are landscapes, ordinary life objects, and people. The framework of his art is his constant research of abstraction and his aim to find the essence and simplicity in our complex world. He uses different, but always analog photographic techniques (24x36 mm, medium format 6x6 cm, large format 9x12 cm, and a Polaroid Land camera). Each of his prints is a unique piece.



Oct 10, 2019 The Art

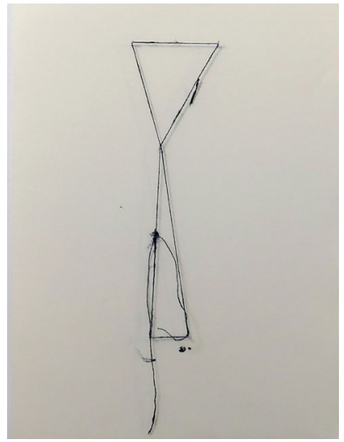
Karin Czermak
Resolving Landscapes

With *Resolving Landscapes*, the Austrian artist Karin Czermak addresses natural areas. Her works often show landscapes made up of abstract color patches. In Karin’s poetic, yet fragmented paintings, shapes appear, overlap and disappear, while colors intertwine and replace each other.

The Science

Peter Turchin
Social Complexity and Collapse

Peter Turchin, just designated as a new group leader at the time of the exhibition, opened the evening with an overview of his plans for the new CSH research group, which will focus on social complexity and collapse.

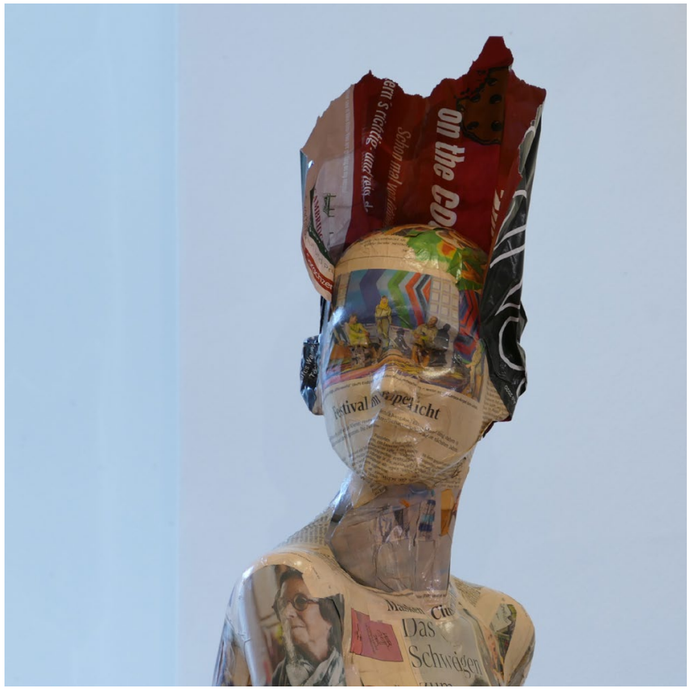


Feb 13, 2020 The Art

Maria Hanl
The Beautiful Form, the Time, the Collapse

Maria Hanl, an Austrian artist and trained cultural anthropologist, is always interested in sociological subsystems. She feels they are often viewed separately because each of them only comprises a small, often very specific realm of knowledge. Hence, Maria says, they always connect to numerous areas of life.

Maria’s artworks are poetic, light, shiny and sometimes seem to fly. She often uses optical illusions, which only upon second glance prove to be manipulations of the material.



The Science

János Kertész
What Do Digital Footprints Tell About Us? From the Grandma Effect to Economic Misbehavior

In his talk, the CSH External Faculty member János Kertész from the Central European University (who had just moved to Vienna together with his alma mater) introduced listeners to analyses of detailed mobile phone records, social media, or the entire body of public procurement database, investigating what we can learn from it about human behavior.

Oct 1, 2020 The Art

Birgit & Peter Kainz
Media—The Second Skin!?

Birgit und Peter Kainz are two socially critical digital photographers and image scientists. Their works always center around the word HUMAN(E). The artists stand for freedom and equality, and they invite their audience to think freely, too.

During the first COVID-19 lockdown in spring 2020, the duo created various pieces from printed media dealing with the pandemic. They also covered nine mannequins with a “skin” exclusively made of newspapers. Printed media just like television, social media and their own news dynamics surround us constantly, the Kainzes say: Media are like a second skin that covers us. We cannot escape.

The Science

Podium Discussion
Crisis and Impact

For the live, but virtual online opening, art curator Stephanie Bourke-Altmann from the Hub discussed with the artists and with Michael Fanizadeh, Head of the Vienna Institute for International Dialogue and Cooperation, Martina Madner, a political journalist, Veronika Mickel-Göttfert, then-district council chairperson of the Viennese district of Josefstadt, and CSH President Stefan Thurner about the impact of the corona crisis.

▶ The discussion was recorded and can be seen on our YouTube channel.

Gov erna nce

It takes more than good research to keep a scientific institution running successfully. Here are the people that keep the Hub up and running.

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MedUni Vienna;
Santa Fe Institute

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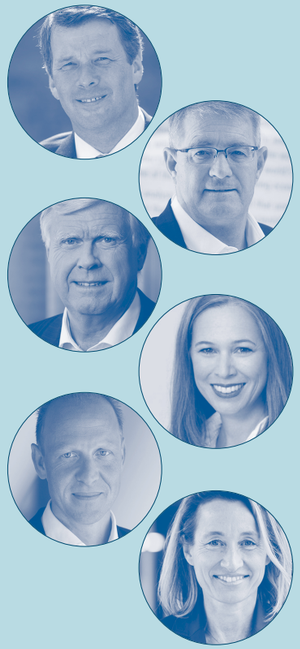

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Pavel Kabat (2016–2019)
Director General and Chief Executive Officer, IIASA

Stefan Pichler (2016–2020)
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Science Advisory Board

The internationally appointed CSH Science Advisory Board (SAB) advises our board and the president in all scientific matters and ensures that the quality of the scientific activities at the Hub is maintained.

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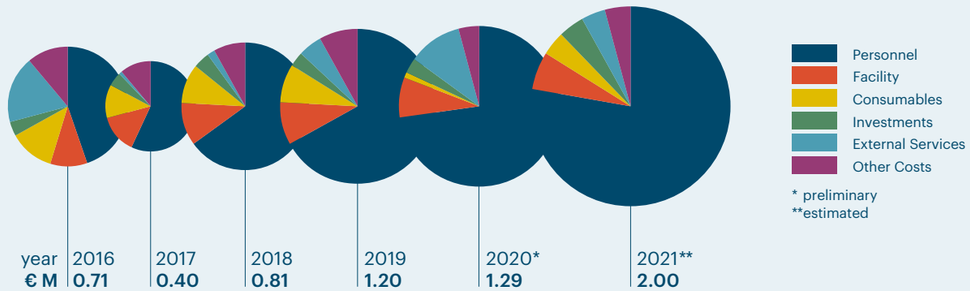

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Federal Ministry Republic of Austria Interior

FFG Promoting Innovation.

WWTF Vienna Science and Technology Fund

FWF Der Wissenschaftsfonds.

ÖBB

ÖNB Oesterreichische Nationalbank Eurosystem

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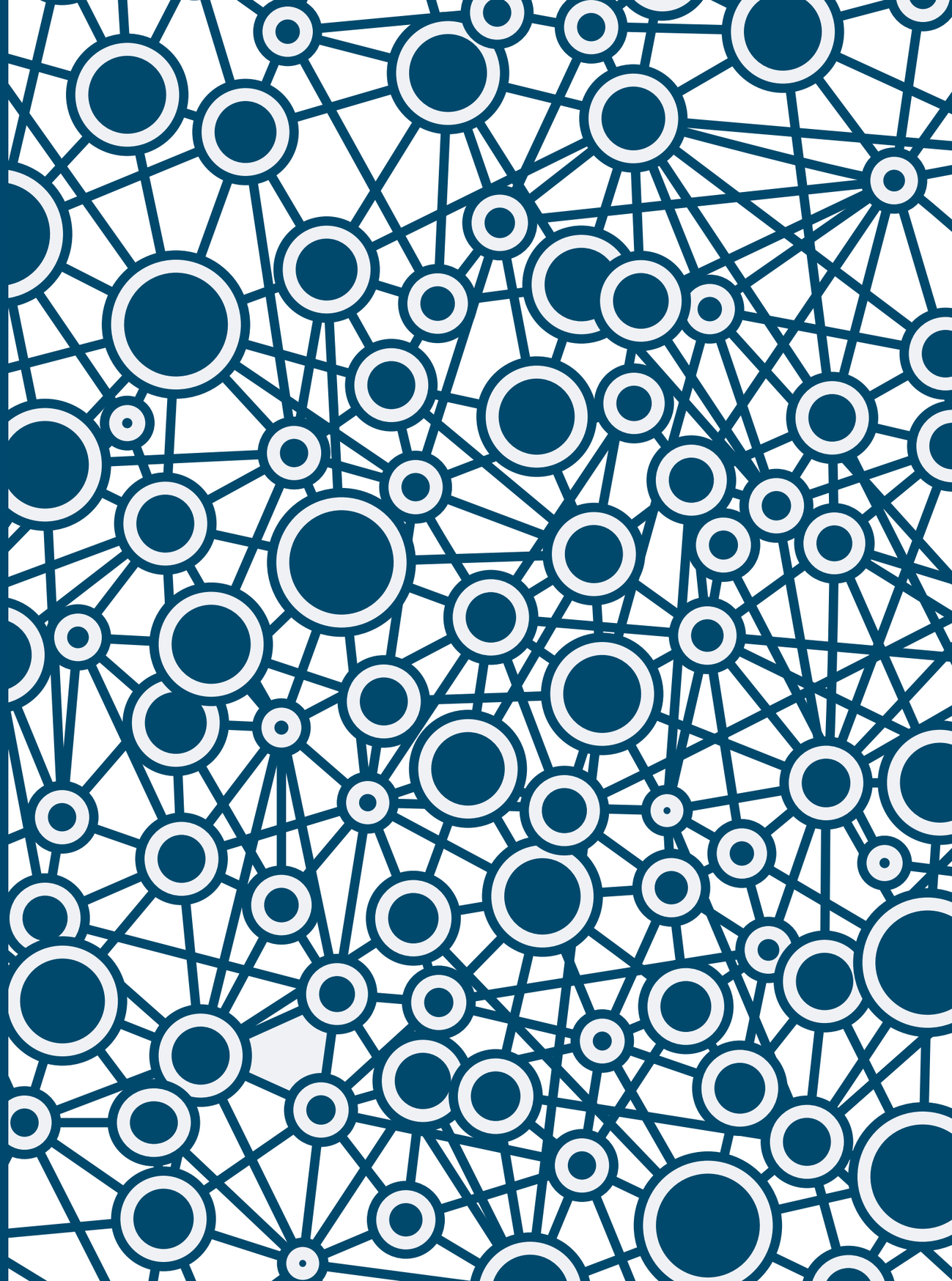

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