Breakdown of Dynamics - (In)Stabilities, Frustration and Critical Transitions

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Systems of many interacting units abound in the social and natural sciences as well as engineering. Networks of friendships influence our opinions, systems of atoms and molecules assemble into regular crystals or amorphous glasses, vehicles on streets create distributed traffic patterns, moving or not. Most of such systems are dynamic and all are complex in the sense that collective system states emerge through self-organization brought about by the simultaneous presence of nonlinearities and interactions. Factors such as interaction delays, potentially complex and time-, connectivity patterns as well as different forms of randomness further complicate the picture. Understanding the mechanisms underlying collective dynamic phenomena of distributed, multi-unit systems thus constitutes a major open challenge of current interdisciplinary research.

Often the collective states of complex systems have a meaning indicating desired or undersired collective features such as normal operation or dysfunction. If properties of the elements, of their interactions or external factors such as temperature or noise level vary, collective features might change qualitatively. For large systems, such transitions typically are not gradual as one might naivly expect. Instead, collective features appear or disappear completely beyond certain 'critical points'. Functionally desired collective states may “break down” and be replaced by other, non-desired ones. For instance, a piece of iron may be (ferro)magnetic below some temperature, but completely non-magnetic for any temperature above it. A street may exhibit free-flowing traffic up to some average number of cars traversing it per hour, but would exhibit congestion if more cars join, with literally the dynamics breaking down.

This talk will provide insights into the forms and challenges in collective states in coupled dynamical systems and their potential transitions. In particular, the breakdown of dynamics may arise in a number of distinctly different ways. I will illustrate (i) instabilities of given collective states, (ii) the switching between two states coexisting under the same conditions, (iii) the total loss of states through Braess' paradox, a phenomenon jointly emerging through flow rearrangements and 'frustration', and (iv) potential countermeasures to respond to certain property changes by imposing additional changes at other system parts. Sample applications come from the field of Network Dynamics, for instance the collective nonlinear dynamics of power grids, see http://networkdynamics.info for our own ongoing research.

Soft Glasses: Frustration and Flow

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The term "glass", if used by a statistical physicist, does not necessarily refer to window glass, but rather points to the following materials: A glass, regarding its state of aggregation, is somewhere between a fluid and a solid, a circumstance resulting in special characteristics. Many of such characteristics are difficult to investigate, as very large measurement times are required. From the viewpoint of material science and statistical physics, glass thus bears still a number of mysteries. In this talk -- introducing a simple model glass of hard spheres -- I will discuss recent developments regarding our understanding of the slow, frustrated dynamics of glasses and their peculiar behavior when exposed to external forces.

On Easing Traffic Jams Utilizing the Nature of the Stability of Traffic Flows

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As a collective system of self-driven particles, vehicular traffic flows exhibit rich collective behaviors such as traffic jams [1-3], which bring huge economic losses and fuel wastes to our society [4]. In some density region, the stability of traffic flows against a braking depends on the amplitude of the braking [5, 6]. That is, after a braking occurs, the final state of a traffic flow in some density region is free (or jammed) if the amplitude of the braking is small (or large). A cutting edge in the breakdown of traffic flows is utilizing this nature of the stability of traffic flows for removing traffic jams. A method in this direction is the Jam-Absorption Driving (JAD), which is a method removing a traffic jam by a single car's driving [7]. Consider a traffic jam moving from right to left direction as shown in Fig. 1. A car performing JAD removes the jam by (i) slowing down and producing a large headway (then, the jam is removed), (ii) following the car ahead of it again. Its braking in the phase of slowing down does not grow to the secondary jam if this braking is small [8]. Easing traffic jams in this direction would need communication systems among cars and knowledges of behaviors of drivers. In this meeting, I would like to discuss the possibility to improve various collective systems such as chemical, biological and social systems utilizing the nature of the stability against perturbations.

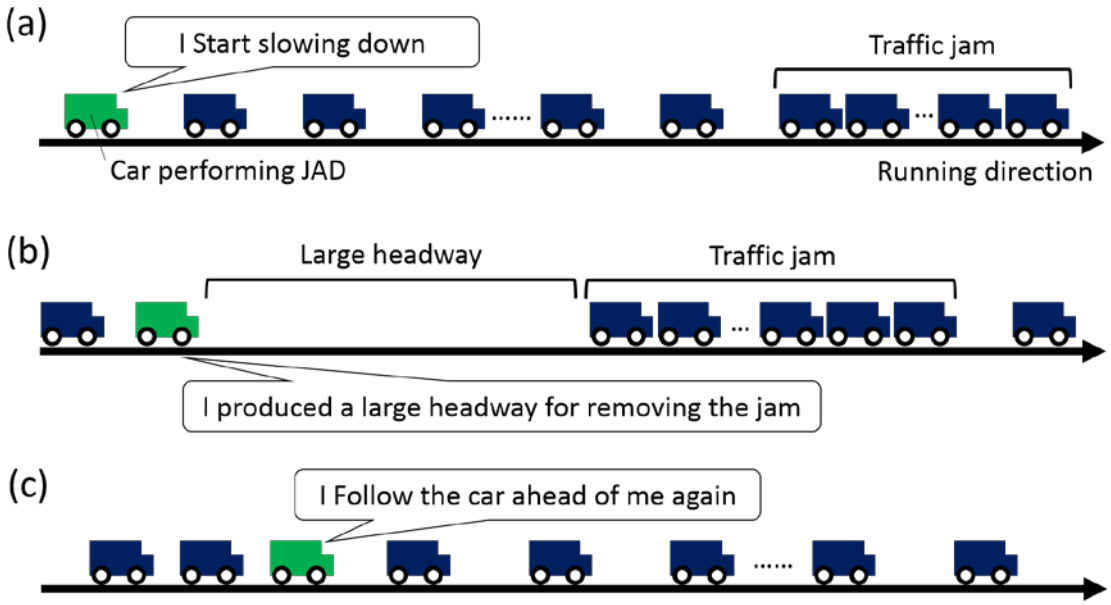

Figure 1: Schematic views of JAD. (a) A traffic jam is moving from right to left direction. The car performing JAD starts slowing down. (b) It produced a large headway. Then, the jam is removed. (c) After disappearance of the jam, it follows the car ahead of it again.

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GLOSSARY

Car-following model【追従モデル】Car-following models represent the following movement of cars. In a typical car-following model, a car determines its acceleration by its headway and the relative velocity to the car just ahead of it. Some car-following models have the instability of traffic flows.

Jam-absorption driving【渋滞吸収運転】Jam-absorption driving (JAD) is a driving method of a single car to remove an approaching traffic jam. JAD is composed of the successive two actions: slow-in and fast-out. In Slow-in, the car performing JAD reduces its velocity and produces a large gap between the tail of the jam and itself. The jam is removed by this enlarged gap. Fast-out is following the car ahead of it again after removing the jam.

Stability of traffic flows：【交通流の安定性】Consider a traffic flow composed of a platoon of cars on a single lane road. After the leading car causes a perturbation, the traffic flow is stable against the perturbation if the perturbation decays. On the other hand, the flow is unstable against it if it grows. The stability of traffic flows depends on the density of cars. Moreover, the stability depends on the amplitude of perturbations in some density region.

Small Spaces Have Big Possibilities

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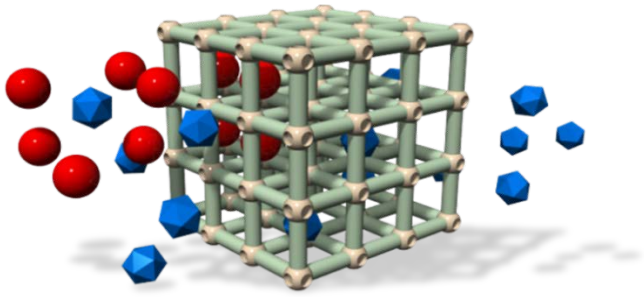
Materials with nanosized void, cavity, and porosity are highly important for industry and life. For example, activated carbons have numerous applications in removing pollutions from air and water, allowing air purification and production of drinking water, respectively. All biopolymers, such as DNA and peptides, are produced by enzymatic catalysis, where highly specific and selective reactions proceed within the regulated and well-organized molecular-scale spaces. In these nanoconfinement system, adsorption of only targeted molecules can be realized, depending on the size, shape, and structure of the nanospaces. Note that molecules accommodated in the nanospace have distinctly different properties and reactivity to those in the bulk state because of the formation of specific molecular assemblies and conformations. With the aid of nanoconfinement, density of adsorbed molecules in the pore is often larger than in the bulk solid. Strong field effect of nanospaces can shift the melting and freezing temperatures of the molecules, and even give chemical stress to induce unusual reactions in the confined nanospaces.

Because of these advantageous features, a variety of nanospaces materials have been created using organic, inorganic, supramolecular, and biomolecular components [1]. Precision design of the molecular building-blocks can allow the production of highly functional nanospaces that are utilized for storage, separation, transportation, catalysis, energy conversion, as well as for medical care and health purposes [2].



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Molecular Guest Houses

モレキュラー 客舎

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You don't have to be a chemist to understand the principles of self-assembly in the field of supramolecular chemistry: Imagine a 3D-puzzle game in which all puzzle pieces perfectly assemble into an object of nanometer dimensions just by mixing and shaking them together. The puzzle pieces are tailor-made molecular building blocks with predetermined binding sites and the forces holding together the final product are weak non-covalent interactions. In this way, larger objects are formed, e.g. nanosized hollow cages or containers in which other molecules can be encapsulated. The latter field of research is called host-guest chemistry and shares similarities with many biological processes, such as the uptake of substrates into the active sites of enzymes. Such supramolecular cages are used for the recognition, transport and stabilization of small molecules.[1] Switchable host-guest systems promise to find application in fields such as uptake & release of molecular cargo, sensing and separation as well as catalysis inside confined molecular environments. The talk introduces into the world of self-assembled cages, with a focus on switchable function, specific guest recognition and reactions inside confined environments.

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Confined Space in Biological Molecules

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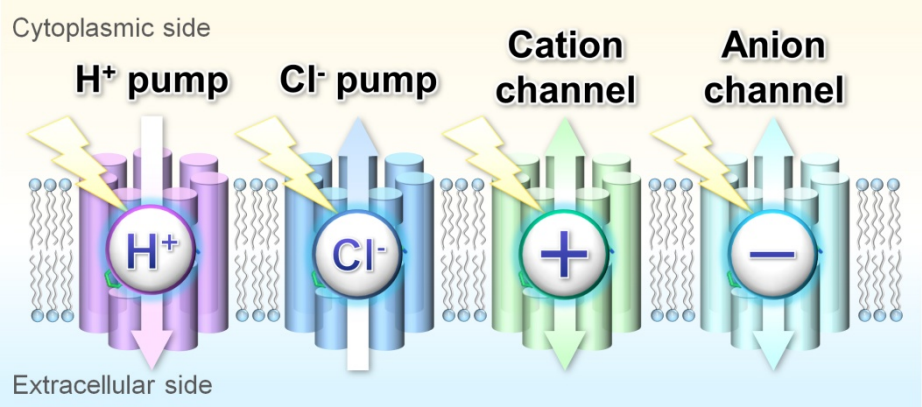
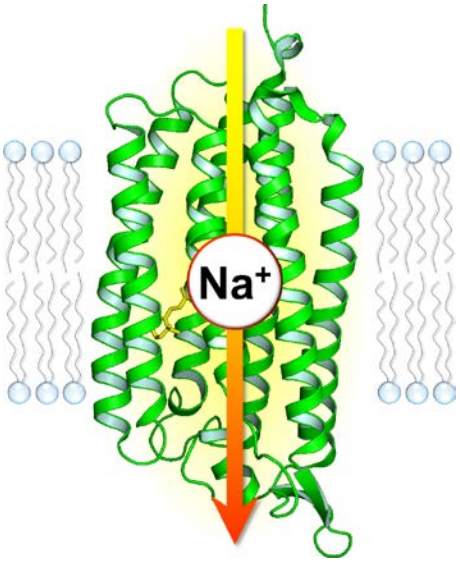
For living organisms, the fundamental processes to maintain their lives are incorporate useful nutrients, exhaust waste substances and avoid unnecessary toxins and chemicals from external world. These processes are called “metabolism”, and all organisms strictly draw a various boundaries in order to spatially control the metabolic reactions. The largest unit of the boundary is cells in which inside of the cellular body is divided from the outside with a lipid bilayer. The inside of cells also has various intracellular structures, such as cytoplasm, nucleus, mitochondria, endoplasmic reticulum, Golgi body and so on, in which organelle-specific biochemical processes take place. From a more microscopic point of view, we can find well-organized and confined space even at the molecular level in biological macromolecules. Especially, proteins have various types of complex confined space in the body to achieve their specific biological functions.

The enzymatic proteins trap the reactant substances (substrate) in their internal cavity and catalytic reaction takes place to efficiently make product. Transporter proteins, existing in cellular membrane, have characteristic confined space connecting the inside and outside of cells with optimized structure to select chemical species (ions, nutrients, wastes and toxins) to be transported. Microbial rhodopsins are one of more specialized transporters which convey ions by light energy [1]. The various types of new rhodopsins have been reported since 2000. Their sophisticated mechanism was studied by structural biological and spectroscopic methods, and they are used as biological tools to control cellular activity of living animals (optogenetics).



Recently we have reported new functional classes of sodium pump rhodopsin (KR2) from marine bacteria living in the Tokyo bay. KR2 transports Na^+ ion from inside to outside of cells by the use of light energy [2]. Further study revealed that the dynamic change of the shape of confined space in KR2 after photo-activation is the key process of Na^+ transport [3].



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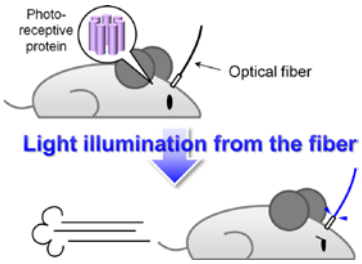
GLOSSARY

Metal-organic framework (MOF)：【金属-有機構造体】are crystalline compounds consisting of metal ions and bridging organic ligands to form extended framework structures.
金属イオンと有機配位子との間で配位結合により組みあがった結晶性構造体。

Optogenetics：【光遺伝学】is a genetic engineering technology in which genes of photo-receptive proteins such as rhodopsin is introduced to animal cells to control the cellular activity and animal behavior by light. Especially, it is most widely used in the studies of neuronal network.
動物の細胞内にロドプシンなどの光受容タンパク質の遺伝子を導入し、光を用いて非侵襲的に細胞の生理活動を制御する技術。特に神経回路ネットワークを調べるために広く応用されている。



Rhodopsin：【ロドプシン】(from Greek (rhódon) for “rose” + ópsis for “sight”) is the photo-receptive membrane protein. There are two types of rhodopsins are known: animal- and microbial rhodopsins. The former acts as the photosensor in animal eyes, and the latter transports various ions by the use of light energy.
光受容型のタンパク質であり、動物の眼球内で光センサーとして機能するものと、微生物の細胞内で光のエネルギーを使ってイオンを輸送するものがある。

Self-assembly (Self-organization)：【自己組織化】is phenomena where some form of overall order or coordination arises out of the local interactions between smaller component parts of an initially disordered system. As examples, crystallization of ice-snow crystals, a morpho butterfly’s structural coloration, and Zebra stripe are well known in nature.
自立的に秩序を持つ構造を創り出す現象のこと。幾何学形状の雪の結晶成長やモルフォ蝶などの構造色を生み出すフォトニック結晶構造、シマウマのゼブラ模様も自然界で見られる自己組織化現象の例である。

Supramolecule：【超分子】is an organized assembly system of two or more molecules held together by non-covalent bondings, such as coordination, hydrogen bonding, and hydrophobic interactions.
複数の分子が共有結合ではなく、比較的弱い結合（配位結合、水素結合、疎水性相互作用など）を介して集合した分子のことを指す。

Effort, Ability and Stereotypes: How to Explain Gender Differences in Educational Outcomes

Ursula Kessels

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Gender differences in educational outcomes encompass many different areas. In this introductory talk, I will present current findings regarding girls' underrepresentation in STEM subjects and boys' lower academic success at school in general.

Much research has focused on girls' underperformance and underrepresentation in STEM subjects and possible reasons for this. Taken together, findings show that in many countries boys still outperform girls on standardized math achievement tests. However, these differences in math competence between the genders are relatively small. Much larger are the differences in motivation-related variables, such that boys score higher on math ability self-concept, report more interest in STEM subjects and choose these subjects more often than girls. Many studies have shown that math and physics are stereotyped as male domains, and as such not compatible with girls' gender-identity. In addition, at least in non-Asian samples, success in STEM is attributed mainly to high ability, and not to effort or hard work. Taken together, girls' underrepresentation in STEM is not caused by lower competencies, but by motivational factors which are related to a perceived misfit between the masculine stereotyping of STEM and girls' self-concept.

More recently, much debate and research has focused on boys' lower academic success in general. In Germany as in many other OECD countries, boys lag behind girls on important indicators of educational success, such as grades, school leaving certificates and type of school. We also see that boys perform worse than girls on standardized verbal achievement tests, have a lower verbal ability self-concept and value the verbal domain less than girls do. The domain of languages is stereotyped as female. In addition, in countries like Germany and in the U.S., academic effort and engagement in general is stereotyped as feminine behavior, and female students value working hard for school more than boys do. Several studies have shown that boys' lower academic success is not caused by lower competencies, but by their lower academic effort and engagement which seems to root in a perceived misfit between the feminine stereotyping of displaying effort at school and boys' self-concept.

Our session on gender, education and inequality will further highlight a) how given gender differences and inequalities are being constructed at school, thus being influenced by many situational factors; and b) how gender interacts with other social categories such as class and age. Finally in the discussion, comparing cultural perspectives from Japan and Germany on this topic will enrich our perceptions of possible causes of gender inequalities in our societies.

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Doing Gender in the Classroom: Ethnographic Explorations

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The presentation will be part of the session „Gender, Education and Inequality“. Schools aim to provide equal chances for all students. However, many studies show that societies‘ differences and inequalities also exist in the field of education. With regards to gender differences for many decades girls were viewed as disadvantaged in relation to boys. In the last years, however, in many countries a new debate has taken over which identifies boys as being educationally disadvantaged.

The first two talks of this session will analyse the significance of gender differences in the field of education from the viewpoint of experimental psychology and survey data. In my talk I will tackle the topic referring to the constructionist “doing gender”-approach. Developed in the field of ethnomethodology, the expression “doing gender” emphasises the role of daily interactions in establishing and maintaining gender roles. Ethnographic fieldwork provides detailed, in-depth descriptions of everyday educational life and practices at particular places and times (Troman, 2006). In my study, an ethnographic approach is chosen to analyse processes of doing gender.

The data, which will be discussed in the paper, is drawn from an ethnographical research project on relationships between teachers and pupils in two inner city primary schools situated in England (London) and Germany (Berlin). The aim of the project was to analyse and compare teacher-student-relationships at both schools as “relations of recognition”. In the paper, especially processes of doing gender in some of the observed interactions will be analysed. With reference to the concept of intersectionality, which describes the interconnected nature of social categorisations such as gender, race and class (Crenshaw 1989), it will be shown that the meaning of gender differences in classroom interactions can only been understood as being strongly linked with other forms of difference and discrimination.

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New Aspects of the Gender Inequality in Education: Focusing on the Case of Japan

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This presentation aims to show the current gender inequality in opportunity for higher education, and show how school institutional arrangements affect students' gender-role attitudes and their educational aspirations.

1. Background

Japan has been understood as a gender-segregated society, implying that the lifetime employment model that characterized the Japanese employment system applied only to male workers. Women were expected to leave their jobs to devote themselves to housework and child rearing when they got married. These rigid divisions of household labor still remain (Brinton ed. 2001; Charles, Chang, and Han 2004; Yu 2009). Such labor market conditions might have affected peoples' aspirations and choice of education. Until the 1980s, girls, with the support of their parents, did not want to advance to higher levels of education because they believed that their academic backgrounds were useless in the Japanese labor market and that men tended to choose less educated women as marriage partners. However, the enactment of the Equal Employment Opportunity Law (1985) and the revision of this law (1999; 2007; 2014) have dismantled the strong gender barrier in the labor market. Consequently, in general, the support for rigid gender-role attitudes has started decreasing.

While the gender-segregated labor market influences educational institutional arrangements, educational practices also affect students' grades, attitudes, and educational choices. School institutions and daily practices implicitly send students wordless messages and reinforce well-known stereotypes in society. Japanese educational sociologists charge that schools reinforce gender stereotypes in accordance with the prevailing gender-role attitudes and gender-segregated labor market (Kimura 1999). Although gender inequality in opportunity for higher education has decreased, Japan is still one of only four countries among members of the Organization for Economic Cooperation and Development (OECD) that display a male advantage in university enrollments. The other three are Switzerland, Turley, and Korea (DiPrete and Buchmann 2013). In addition, it was observed that in Japan, boys achieved higher grades for STEM subjects and displayed a preference for these fields of study.

2. Data, Analyses, and Results

In this presentation, I indicate that while gender stereotypes and inequality persist in education, certain educational institutions may change people's attitudes and educational choices. First, using data from Social Stratification and Social Mobility (SSM) surveys, I will show the relationship between educational

background and gender-role attitudes as well as changes in Japanese gender-role attitudes during the 1990s and 2000s. Second, using the data of nationwide questionnaire surveys conducted among Japanese senior and junior high school students, I show different educational aspirations based on gender and their gender-role attitudes. According to the data, boys were more likely to expect advancement to university compared to girls. On the other hand, a larger percentage of boys, especially for those whose performances were not good, had extremely low educational aspirations compared to girls. While the gender inequality in educational achievement is decreasing, the issue of low performance by boys recently appeared. This analysis shows that a decrease in the average academic grade seems to induce increased number of juvenile delinquents. Finally, I examine the relationship between school institutions and students' attitudes. While educational aspirations were closely related to school track for both genders, they were related to social background such as father's occupation and household income for only boys. In addition, while girls in academic school tracks might decrease the gender stereotype and were less likely to choose gender-typical fields of study at higher educational institutions, boys in academic tracks were more likely to choose gender-typical fields of study. The implications of these results are discussed in the presentation.

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GLOSSARY

Aspiration：【アスピレーション】means a strong desire or hope to have a high social position or educational attainment level.

Attribution:【帰属】Attribution is a judgement about the cause of a behavior or outcome – for example to success or failure on a task (achievement attributions). A given success in mathematics might be attributed to a students' high ability and/or to his or her high effort.

Doing Gender:【ジェンダーの実践】Developed in the field of ethnomethodology, the expression "doing gender" emphasizes the role of daily interactions in establishing and maintaining gender roles.

Gender:【ジェンダー・社会的性】 Often used in distinction to the term "sex", which refers to biological aspects of maleness and femaleness , "gender" implies the social and cultural aspects of being male or female and hence the changeability of gender roles.

Gender-Identity【ジェンダー・アイデンティティ・性自認】Gender identity as a person's sense of self as a female or male (Zucker & Bradley, 1995)

Hidden Curriculum：【隠れたカリキュラム】Hidden curriculum means unwritten, unofficial, and unintended lessons, values and viewpoints that students learn in school, and it consists of the implicit academic, social, and cultural messages while they are in schools. Social scientists pointed out that it reinforced the gender stereotyped socialization through school activities.

Intersectionality:【インターセクショナリティ】The term intersectionality describes the interconnected nature of social categorizations such as gender, race and class. In relation to social inequality the concept of intersectionality makes clear that it has to be understood as intersection of different forms of discrimination.

PISA study:【PISA調査】: The Programme for International Student Assessment (PISA) is a worldwide study by the Organisation for Economic Co-operation and Development (OECD) in member and non-member nations of 15-year-old school pupils' scholastic performance on mathematics, science, and reading. It was first performed in 2000 and then repeated every three years.

Self-concept:【自己概念】The self-concept is a collection of beliefs about oneself and embodies the answer to the question "Who am I?"

SES:【社会経済的地位】 Socio-Economic-Status; measure of an individual's economic and social position in the society. The PISA study uses occupational data for both the student's father and student's mother and the level of parental education when describing their socio-economic-status.

GLOSSARY

SSM survey : 【SSM調査】”SSM” is the abbreviation of social stratification and social mobility. The SSM survey is one of the most famous social surveys in Japan focusing on social class and occupational careers, and has been conducted every decade since 1955.

STEM subjects:【STEM教科・理系教科】Acronym for Science, Technology, Engineering and Mathematics.

Stereotype:【ステレオタイプ】A stereotype is a generalization about a group of people in which identical characteristics are assigned to virtually all members of the group, regardless of actual variation among the members. Gender stereotypes pertain to beliefs about the attributes of women and men. These gender stereotypes are not only descriptive (beliefs what attributes men and women actually possess), but also prescriptive (what attributes men and women ought to have or ideally would have).

Tracking : 【トラッキング】”Tracking” originally refers to the practice of dividing into separate classes within a school on the basis of academic ability in the United States. In comparative perspective, tracking also indicates curricular differentiation between schools at the secondary educational level. In Japan, placement in differentiated secondary school tracks is determined by high school entrance examination. In Germany, differentiated curriculum begins with entry into the lower secondary level, and placement of tracks is determined by grades and test scores (LeTendre, Hofer, and Shimizu 2003).

The Different Flavors of Antiviral Defense

Lennart Randau

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Bacteria and Archaea are required to adapt to the continuous presence of viral threats and their co-evolution shapes the genomes of these biological entities. CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats)-Cas (CRISPR-associated) are prokaryotic immune systems that utilize small CRISPR RNAs (crRNAs) to identify and destroy viral genomes and conjugative plasmids (1). The genomic CRISPR loci are transcribed into a long precursor RNA that is processed by endonucleases into mature crRNA. Every crRNA contains a so-called spacer sequence that can be derived from a sequence (i.e. the protospacer) of a mobile genetic element, e.g. a virus. An attack by a specific virus can be recognized via base-complementarity between the spacer sequence and the viral DNA and the crRNA can direct a Cas protein complex to degrade the invasive DNA (2). The crRNAs are incorporated into interference complexes that can either contain a single Cas protein subunit (e.g. Cas9 or Cpf1) or are assembled with multiple filament-forming subunits (e.g. Cascade). Modulating the crRNA sequence allows for site-specific DNA cleavage, which constitutes the basis for genome editing applications. In these cases, Cas protein interference complexes act as programmable DNA scissors, which allow for the alteration and, providing suitable DNA templates, for a desired correction of the targeted DNA sequence.

I will review the landscape of highly divergent CRISPR-Cas systems in Bacteria and Archaea and will highlight important structural and functional differences which can impact target specificity. Our laboratory studies minimized Cascade complexes and their assembly, structure and targeting mechanism will be discussed (3,4). Recently, we described a minimal variant of the Type I-F CRISPR-Cas system (Type I-Fv) that exists without small and large subunits. We were able to transfer this system into *Escherichia coli* and could demonstrate its activity against phage lambda attacks. A purified recombinant complex consists of the crRNA endonuclease Cas6, several copies of a Cas7-like backbone protein and a third Cas protein which does not fit into known Cas protein families. We hypothesize that this protein can fulfil functions of the missing large and small subunits, which are proposed to involve interactions with the target DNA. The backbone protein forms filamentous structures around single-stranded RNA sequences. This motivated us to vary the length of the guide portion of the crRNAs. We obtained elongated and shortened Cascade complexes that cap and protect the longer and shorter crRNA variants. The number of backbone protein subunits in these complexes varied accordingly. These synthetic Cascade variants display altered DNA specificity, which suggests potential benefits for genome engineering applications.

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Single Base Pair Genome-Editing Technology and Its Future Applications

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Programmable nucleases, including zinc-finger nucleases (ZFNs), transcription activator like-effector nucleases (TALENs), and Clustered Regulatory Interspaced Short Palindromic Repeats (CRISPR)/CRISPR-associated 9 (Cas9), can be used to introduce double-strand breaks (DSBs) in the genome. By then exploiting the endogenous DSB repair pathway in cells, genomes can be edited to disrupt, introduce, invert, delete, or correct genes. Genome editing is now used in medical research to, for example, identify causal mutations underlying inherited diseases [1], establish disease models via induced pluripotent stem (iPS) cells [2], and treat human immunodeficiency virus (HIV) infection or acquired immune deficiency syndrome (AIDS) [3].

Genome-wide association studies have identified a large number of single nucleotide polymorphisms (SNPs) that are associated with human diseases and with physical traits such as height, olfactory sensitivity, and skin color. SNPs in coding regions or splice sites that are predicted to drastically alter protein structure or function are suspected, with good reason, to underlie the associated disease or trait. In these instances, the functional analysis of the SNP becomes relatively straightforward. However, noncoding SNPs cannot be easily characterized. Therefore, experimental characterization of these SNPs remains a challenge. This situation is especially true for single nucleotide variations that are strongly associated with rare diseases.

One of the most straightforward methods to characterize SNPs, single nucleotide variations, or major allelic variants, is to engineer them directly into the genome. Unfortunately, single base pair editing through spontaneous homologous recombination is impractical or unachievable. Therefore, efficient single-base-pair editing technologies, based on programmable nucleases, are required [1]. Seamless genome editing, in which target nucleotides are mutated without leaving a footprint, is also critical, especially in regenerative medicine [4]. Importantly, the efficiency of seamless genome editing largely depends on the system and technique used.

In this presentation, I will focus on single base pair editing and related techniques, especially those used for seamless genome editing in human cells. I will also examine the merits and demerits of each technique, and explore potential technical improvements.

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Prospects of Genome Editing in Fundamental and Applied Plant Research

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Plants do not have an adaptive immune system or cells specialized on defense. Instead, plants rely entirely on a two-tiered innate immune system, which can be activated in a cell-autonomous manner [1]. On the one hand, plant cells express a suite of so-called pattern recognition receptors (PRRs) on the cell surface, which can recognize non-self molecules characteristic for potential invaders, such as bacteria or fungi [2]. On the other hand, plant intracellular immune receptors can recognize effector proteins delivered to host cells by pathogenic microbes [3]. Effector proteins generally serve to subvert plant immune responses or facilitate nutrient acquisition by the pathogen, but effector recognition induces a rapid and efficient immune response. This co-evolutionary conflict is believed to drive extensive variation in pathogen effector and plant immune receptor repertoires.

Intensive studies on plant innate immunity and technological advances allowed the identification of many genetic resistance determinants in diverse plant species. Also, the genomes and effector complements of microbes isolated from infected plants can now rapidly be catalogued. For many of these effectors, the mode of action and their targets within the plant cell have been identified. This knowledge provides a rich seam for engineering disease-resistant crop varieties. Programmable nucleases can be applied to alter pathogen effector targets, rendering effectors inactive during infection [4]. Also, nucleases can be exploited to engineer beneficial traits in elite cultivars, thus accelerating classical breeding programs. Genome editing may also be used to dissect disease resistance pathways in virtually any plant species, enabling researchers to expand from established model species. Applications and limitations for genome editing in both basic and applied plant research will be discussed.

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GLOSSARY

Genome editing：【ゲノム編集】Genome editing is a type of genetic engineering in which DNA is inserted, deleted, or replaced in the genome of an organism using programmable nucleases, or "molecular scissors." These nucleases create site-specific double-strand breaks (DSBs) at desired locations in the genome. The induced DSBs are repaired through nonhomologous end-joining (NHEJ) or homologous recombination (HR), resulting in targeted mutations (or 'edits').

Genome-wide association study：【ゲノム全領域関連解析】In genetic epidemiology, a genome-wide association study (GWA study, or GWAS), also known as a whole genome association study (WGA study, or WGAS), is an examination of many common genetic variants in different individuals to determine whether any single variant is associated with a trait. GWASs typically focus on associations between single nucleotide polymorphisms (SNPs) and major diseases.

Homologous recombination：【相同組換え】An event where nucleotide sequences are exchanged between two different regions of DNA fragments or chromosomes with similar nucleotide sequences.

Noncoding SNPs: 【非コードSNPs】SNPs locating outside of protein-coding regions.

Programmable nuclease：【改変可能なDNA切断酵素】 Programmable nucleases create site-specific DSBs at desired locations in the genome. The versatility of these nucleases arises from the ability to customize the DNA-binding domain to recognize virtually any sequence. Currently, four families of programmable nucleases are used: Meganucleases, Zinc finger nucleases (ZFNs), Transcription Activator-Like Effector-based Nucleases (TALEN), and the CRISPR-Cas system.

Regenerative medicine: 【再生医療】A research field aiming to restore human cells, tissues, and organs to regain normal function.

Single-nucleotide polymorphism (SNP)：【一塩基多型】A single nucleotide polymorphism, often abbreviated as ‘SNP’ (pronounced ‘snip’; plural ‘snips’), is a variation in a single nucleotide that occurs at a specific position in the genome, where each variation is present to some appreciable degree within a population (e.g. >1%).

Machine Consciousness: a Dream to Build a Strong AI

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A long-standing dream in research on artificial intelligence (AI) is to build a *strong* AI termed by Searle (1980), which understands and processes the input, unlike a *weak* AI which just processes it as programmed. A *conscious machine*, if exists, shall take a form of this strong AIs, as its conscious processing should be autonomous and essentially independent from the external inputs.

Toward realization of this dream, we need a mathematical formulation on what understanding is. In the present study, starting off by revisiting Shannon's mathematical theory of communication, I argue that it is a model of information transmission but not that of information understanding, because of its common codebook shared by the sender and receiver. Then I will give a review on the recent development of a new information theory, called integrated information theory, proposed by Giulio Tononi.

I outline the steps to build a model of information understanding, and discuss to what extent the current research has made for it. Finally, I would like to discuss the relationship of the machine consciousness and other known problems in AI research, such as the symbol grounding problem and frame problem.

How Do We Learn and Think about Our World and Become Language Ready?

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How can anticipatory probabilistic learning principles enable the development of compositional concept structures and make us language ready? Even though the underlying learning principles can be formalized by means of free-energy-based inference, it seems necessary that additional structural biases, which enable us to identify behaviorally relevant structures in the environment, need to be incorporated. In this talk I will highlight several fundamental structures and show how more complex, compositional conceptualizations can develop.

While entities can be located generally anywhere in space, mainly relative spatial arrangements and local interactions are critical to enable both, entity behavior predictions and goal-directed entity manipulations. As a result, the predictive system can be modularized to enable (i) the distinction of space from entities with their properties, (ii) the flexible, temporary activation of relative spatial relations between different entities, (iii) the dynamic adaptation of these relations while executing or observing particular interactions, and (iv) the development of a, probably motor-grounded, concept of forces, which predictively encodes the result of relative spatial and property manipulations dynamically over time. Furthermore, seeing that entity interactions typically have a beginning and an ending, the predictive system should focus on segmenting sensorimotor interactions into events and event boundaries. Essentially, events may be characterized as the unfolding of particular sets of temporal predictive models, which encode the expected consequences of particular entity interactions. Event boundaries then identify those situational aspects that are crucial to enable the beginning of an event and that mark the end of an event – such as the establishment of object contact and contact release.

When learning along these structural principles, behavior can be generated goal-directedly by means of active inference from very early on. The addition of internal motivations in the form of homeostatic variables can focus the system on those environmental interactions that are motivationally relevant. As a result, behavior strives to generate those motor forces that are expected to push internal, body-grounded states towards homeostasis. Moreover, behavior will focus cognitive development towards bodily relevant, sensorimotor grounded, event-oriented conceptualizations.

Besides tendencies towards particular modularizations and segmentations, our mind has developed highly versatile behavioral and social capacities. Tool usage is unprecedented and relies on the ability to integrate different tools highly flexibly into our own body schema. Social interactions require the integration of other humans into our cognitive apparatus – with the tendency to assign similar capabilities (physical and mental) to them. The capacity to flexibly integrate tools and humans into our minds, plus the addition of the motivation to flexibly interact with them, seems to open up the possibility to imagine different perspectives on the self and on the world. It becomes possible to assign roles, such

as actors, means, and recipients, when observing, executing, or imagining particular spatial interactions. Due to this mental flexibilization, also socially-oriented compositional concept structures develop, which seem to make our minds language ready.

How Can We Assess “Machine Consciousness”? – From the Perspective of Integrated Information Theory

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Imagine that you are locked in a strange room. From outside of the room, a question written, in “Chinese” is passed to you. Suppose that you do not know anything about Chinese. Your task is to answer the question by referring to a miraculous book where appropriate answers to all possible questions are written in Chinese. You copy the answer from the book, write it down in a paper, and pass it to a person outside. In this way, from the viewpoint of the outside person who does not know how the questions are answered, it seems that you are able to converse in Chinese. However, from the inside (your) point of view, you are not at all “conscious” of meanings of the conversation. This is a modified version of the famous “Chinese room” though experiment presented by the philosopher John Searle. This thought experiment strikingly illustrates a critical difference between the ability of doing something and that of being conscious of something. Recent advancement of artificial intelligence has been rapidly broadening the scope of machine’s capability of doing something. However, it has not yet achieved the machine’s capability of being conscious of something. To address this issue, we need to focus on internal viewpoint of a machine, i.e., how a computation is carried out inside the machine while we should not be distracted by the external viewpoint, i.e., what kind of computation the machine can do. Integrated information theory of consciousness (IIT) helps us clarifying this important difference between internal and external viewpoints of information processing. In a nutshell, IIT states that a system has to “intrinsically” generate information and integrate information to generate consciousness. In this talk, I will discuss how we should assess machine consciousness from the perspective of IIT.

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GLOSSARY

Artificial general intelligence (AGI):【汎用人工知能】 is the intelligence of a (hypothetical) machine that could successfully perform any intellectual task that at least a human being can.

Chinese room argument:【中国語の部屋問題】 is a thought experiment presented by the philosopher John Searle to challenge the claim that it is possible for a computer running a program to have a mind and consciousness in the same sense that people do.

Frame problem:【フレーム問題】 is the challenge of representing the effects of action in logic without having to represent explicitly a large number of intuitively obvious non-effects.

Integrated information theory:【意識の統合情報理論】 is the attempt to explain what consciousness is and why it might be associated with certain physical systems, and then predict whether the system is conscious, to what degree it is conscious, and what particular experience it is having.

Machine consciousness:【人工意識】 (also known as artificial consciousness or synthetic consciousness) is a research field focusing on analyzing, modeling, and exploiting the way that humans and animals are conscious, and then applying these discoveries to machines.

Strong AI:【強いAI】 (also known as full AI) is the artificial intelligence with the right inputs and outputs that would thereby have a mind in exactly the same sense human beings have minds.

Symbol grounding problem:【シンボルグラウンディング問題】 is the problem of how words (symbols) get their meanings, and hence to the problem of what meaning itself really is.

Synthetic Intelligence:【合成知能】 is an alternative term for artificial intelligence which emphasizes that the intelligence of machines need not be an imitation or any way artificial.

Weak AI:【弱いAI】 (also known as applied AI, narrow AI, or weak AI) is non-sentient computer intelligence or AI that is focused on one narrow or specific task, in contrast to strong AI.

"The Future of Ice" Judged by the Things Past

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Recently, terrestrial ice (mainly small glaciers and ice caps) and Arctic sea ice lose their mass[1)]. It is well known the mass loss is due to global warming caused by **anthropogenic greenhouse gases** (e.g. CO_2). In order to reliable judgment of the mass loss, appreciate clarification on the mechanism of the mass loss is required. One promising way to make clear the mechanism is from **paleo environmental reconstruction**. "Things present are judged by the things past."

I will present the mechanism how ice on Earth gain and/or lose their mass in recent epoch. One key factor is positive feedbacks among air temperature, concentration of greenhouse gases and ice extent on Earth[2)]. Positive feedback is a process that occurs in a feedback loop in which the effects of a small disturbance on a system include an increase in the magnitude of the perturbation. That is, ice extent produces more of low air temperature due to high albedo of ice which in turn produces more of ice extent.

The other is the fact that recent CO_2 concentration of about 400 ppm[3)] is unprecedented circumstance for our homo sapiens. Homo sapiens became conspicuous from two hundred thousand years (200 ka) ago. During the recent 200 ka, CO_2 concentration fluctuated from 180 to 300 ppm[4)], showing synchronization with air temperature fluctuation. What will make such high level of CO_2 concentration in near future? The answer is asked for model studies of near future prediction.

anthropogenic greenhouse gases: 【人為由来温室効果気体】Since about 1750 human activity has increased the concentration of carbon dioxide and other greenhouse gases.

paleo environmental reconstruction: 【古環境復元】to reconstruct the biological, chemical, and physical nature of the environment at the collection site at the time of deposition, by using proxy archives (marine sediment core, ice core and so on)

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Climate Variability and Ice Sheet Dynamics During the Past Three Glaciations

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A key concept in geology is that the “present is the key to the past.” Similarly, past periods in the Earth’s history can be seen as analogs for future change. Here I will present a reconstruction of abrupt climate variability as recorded by North Atlantic sediments over the last 300,000 years. During the Last Glaciation, which lasted from roughly 70,000 to 15,000 years ago, large continental glaciers covered large portions of North America and Eurasia. Though climate was globally much colder than modern, it was also much less stable, with rapid warming and cooling events occurring often every several thousand years. Times of severe cooling and glacial expansion are marked in the North Atlantic sedimentary record by thick deposits of iceberg-rafted debris (IRD).

Under modern climate conditions, warm, saline water is transported northward by the Atlantic Gulf Stream, where it cools, reaching a critical density, and sinks to form North Atlantic Deep Water. This sets up a global thermohaline, overturning circulation that pulls heat northward, warming the Northern Hemisphere. However, such thick IRD deposits indicate that large numbers of icebergs were calved from surging glacial ice streams, drastically altering the salinity budget of the North Atlantic Ocean, and slowing or even stopping the thermohaline circulation, resulting in substantial cooling in the Northern Hemisphere and coincident warming in the South. The North Atlantic sedimentary record indicates that the Penultimate Glaciation, lasting from about 190,000 to 130,000 years ago experienced fewer (and less severe) such fluctuations, whereas the preceding glaciation (300,000 – 240,000 thousand years ago) was very similar to the Last Glaciation. The reason for this seems to have been differing European and North American ice sheet configurations.

Ice Physics Studies Using Deep Ice Cores in the Light of Global Warming

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Our changing climate will affect human lives in manifold ways. Especially sea-level rise is driven by diminishing amounts of snow and land ice. The cryosphere as part of the Earth's climate system provides interconnecting feedbacks between its components, leading to multifaceted changes. To understand these feedback mechanisms we have to consider the various interactions between the atmosphere, the oceans and the ice covering both polar land and seas. The state and evolution of Earth's glaciers and ice sheets play a key role therein and thus profound ice physics knowledge with respect to ice sheet dynamics is required. Ice sheet dynamics on multiple scales, from microscopic processes to continental-sized phenomena, are in the focus of scientific attention to improve climate predictions on a global scale.

The state and evolution of ice sheets and glaciers is partly recorded in deep ice cores drilled through the Antarctic and Greenlandic ice. Advanced analysis of ice core material can teach us the climate history of our planet and reveal physical mechanisms leading to ice motion. The mapping of ice micro-structures, which are reflecting the deformation and recrystallisation processes that control ice sheet flow reveal the active processes in the material. The connection between ice dynamics, microstructures, process modelling as well as phenomenological modelling of ice deformation then tests and completes our current understanding of ice sheet dynamics and result in improved future projections.

GLOSSARY

Glaciation/ Interglaciation 【氷期・間氷期: Ice ages occur roughly every 100,000 years during the Late Pleistocene in apparent response to changes in the amount of incoming solar radiation caused by variations in the Earth's orbit. Relatively ice-free periods between major ice ages are called interglaciations, and Ice ages are known as glaciations.

Iceberg-Rafted Debris (IRD) 【氷山起源の岩屑】: Glaciers flow like rivers over continental bedrock, scraping rock fragments from the surface and incorporating them in the basal portion of the glacier. When a glacier calves an iceberg, as it melts in the ocean, the continental rock fragments drop out and settle on the ocean floor.

Sediment Core【海底堆積物コア】: The ocean floor can be sampled by taking pushing long, hollow pipes into the subsurface. These recover the sedimentary layers that have been deposited over time and are a primary marine geological tool.

Stadial/ Interstadial 【亜氷期・亜間氷期】: A relatively warm period within a glaciation is known as an interstadial, and relatively cold periods are known stadials.

Thermohaline Circulation 【熱塩循環】: The northward traveling North Atlantic Gulf Stream is a current with relatively high salinity, and therefore increased density. As this water cools in the Nordic sea, density is further increased such that the water sinks to a depth of several kilometers, and beings flowing southward. Additional water is pulled from the south to replace the subducted water, transporting heat to the Northern Hemisphere.