

# **SESSION I**

**SESSION FIELD**  
**CHEMISTRY**

**SESSION TITLE**  
**CHEMISTRY OF "ORIGINS OF LIFE"**

# SESSION I

## Chemistry

### Chemistry of "Origins of Life"

---

**Chair: Tomoaki MATSUURA**  
**Graduate School of Engineering, Osaka University**

It remains unclear, where and how the first living matter (*i.e.*, life) begins. We have learned from the fossil records the existence of dinosaurs and other mysterious creatures, but there are no records about the first living matters that is believed to have emerged about 3.9 billion years ago. Under such circumstances, synthesizing molecules constituting the cell, molecular systems, and ultimately the entire cell only from defined components and under defined conditions is one of the strategies to gain insight into the origin of life (Szostak, Bartel and Luisi, *Nature*, 2001).

"Origin of life" can be classified into two different levels. The first is the origin of biological molecules, such as the amino acids, nucleotides, and lipids from non-biological molecules. Early Earth is likely to have had only simple chemicals such as methane, ammonia and hydrogen. How can the biological molecules emerge? Urey and Miller performed a chemical synthesis in a possible primitive Earth condition, and found that amino acids can be synthesized (*Science*, 1953). As such, synthesizing biological molecules and/or identifying conditions that enable their synthesis will give insight into the origin of biological molecules. Dr. Danger will present the topic related to the origin of biological molecules.

The second level is the origin of the molecular system. Molecules *per se* are necessary but not sufficient for life. If we observe a mixture of components from disrupted *Escherichia coli* containing all the molecules originally present, no spontaneous regeneration of living cells takes place. Molecules must be coordinated in the correct order to form a molecular system that exhibits properties of a living cell. However, it is often difficult to artificially synthesize or construct such molecular systems. Accordingly, synthesizing molecular systems that exhibit cell-like properties and identifying conditions to synthesize such system will give insight into the origin of such molecular system. Dr. Toyota will present the topic related to the origin of molecular system exhibiting a cell-like behavior.

One of the ultimate goals in the field of origin of life is to synthesize an artificial cell, one of the most complex molecular systems. When this is achieved, it shows one possible route for the origin of cell, *i.e.*, emergence of livings from non-living materials. In this session, the significance and the impact of research on the artificial cell assembly will also be discussed.

**Speaker: Taro TOYOTA**  
**The University of Tokyo**

#### I - Closed boundary composed of amphiphilic molecules

At the prebiotic era of the Earth, the emergence of a closed boundary composed of organic molecules was inevitable for the birth of the common ancestor of living cells. The living cells commonly have closed membranes made of lipid binding phosphate, *i.e.* phospholipid. Like detergents, phospholipids are categorized to amphiphilic molecules (called as amphiphiles) which have both the water-soluble part (phosphate) and the water-insoluble one (lipid). Moreover, phospholipids can form closed membrane in water with no assistance of

DNA or proteins. But, researchers think that the cell-originated phospholipid is too complicated to argue that it consisted in the closed boundary at the prebiotic era. So far, Prof. Nakatani and Prof. Ourisson (Louis Pasteur University) proposed a hypothetical pathway of chemical evolution of a phospholipid. Prof. Walde (ETH) reported that fatty acid which is simpler amphiphile than phospholipid forms closed membrane (vesicle) in water at a certain concentration and pH. Prof. Deamer (UCSC) found that fatty acid extracts from a meteorite form vesicles in water. Therefore, the closed boundary or membrane composed of simple amphiphiles has drawn much attention as a powerful model of the container for the common ancestors of living cells.[1]

## II - Design of molecular system realizing cell-like dynamics of closed boundary of amphiphiles.

How does the closed boundary of amphiphiles show cell-like dynamics linked to their metabolic reactions? This question is significant and incentive for not only the issue on origins of living cells but also supramolecular chemistry and soft matter physics. To approach this question, we have focused on designing ad hoc molecular systems where the closed boundary of amphiphiles shows the cell-like dynamics. The amphiphiles consisting in our molecular systems are designed based on the two aspects: the structure of the water-soluble part and the chemical reaction of the water-insoluble part. According to Kunitake's reports that artificial amphiphiles containing ammonium ions as the water-soluble part forms closed membrane in water,[2] we adopted this water-soluble part because several sorts of phospholipids contain ammonium ions. Maillard reaction is one of the nonenzymatic chemical reactions which are expected to be involved in origin of life.[3] We thus installed the essence of Maillard reaction into the water-insoluble part of the amphiphile. Using such synthesized amphiphiles, we realized growth and self-division dynamics of vesicles and self-propelled motion of amphiphile-oil complex droplets.[4,5] Addition of reactive amphiphiles to produce the component molecules of vesicles, micrometer-sized vesicles containing an amphiphilic catalyst repeatedly grew and self-divided under a microscope. In the case of amphiphile-oil complex droplets which have micrometer scale diameters, they exhibited the self-propelled motion and chemotaxis behavior to the added amphiphiles.

## III - Constructive approaches for issue on origin of living cells.

The constructive approach for origins of living cells is successfully progressing with the development of the closed boundaries of amphiphiles and the analysis on their dynamics. The merit of this approach to the origins of life is that all component molecules are well defined after synthesis and purification. For example, Prof. Szostak's group (Harvard University) and Yomo's group (Osaka University) independently constructed the evolutionary process of informational substances using vesicles or droplets. Sugawara's group (University of Tokyo) developed the vesicle proliferation system assisted by amplified DNA inside of the vesicles. Namely, the researchers take more interest in the next stage of the constructive approach for emergence of genotype and phenotype in origin of living cells. In the present talk, an idea bridging growth/self-division dynamics and self-propelled motion is discussed for nonbiological acceleration of the evolutionary process based on the closed boundary of amphiphiles.

## IV - Conclusion

The present talk briefly reviews the history of researches on the closed boundary of amphiphiles and ad hoc molecular systems exhibiting cell-like dynamics. These findings contribute to a model for origins of life. Moreover, they provide a novel experimental subject for chemistry, namely, the robustness of molecular assembly in a non-equilibrium condition.

## V - References

- 1 'Synthesizing life', J. W. Szostak, D. P. Bartel, P. L. Luisi, *Nature*, 409 (2001), 387-390.
- 2 "A totally synthetic bilayer membrane", T. Kunitake, Y. Okahata, *J. Am. Chem. Soc.*, 99 (1977), 3860-3861.
- 3 "Action of Amino Acids on Sugars. Formation of Melanoidins in a Methodical Way", L. C. Maillard, *Compt. Rend.*, 154 (1912), 66-68.
- 4 "Population Study of Sizes and Components of Self-Reproducing Giant Multilamellar Vesicles", T. Toyota, K. Takakura, Y. Kageyama, K. Kurihara, N. Maru, K. Ohnuma, K. Kaneko, T. Sugawara, *Langmuir*, 24 (2008), 3037-3044.
- 5 'Self-Propelled Oil Droplet Consuming "Fuel" Surfactant', T. Toyota, N. Maru, M. M. Hanczyc, T. Ikegami, T. Sugawara, *J. Am. Chem. Soc.*, 131 (2009), 5012-5013.

**amino acids** 【アミノ酸】 is a building block of proteins. Protein is one of the most abundant molecules in the cell, and does most of the chemical reaction inside the cell, and defines the shape of the livings.

タンパク質を構成する部品。タンパク質は細胞を構成する主要成分であり、化学反応をおこすだけでなく生物の形を決める役割も果たしている。

**Amphiphile** : 【両親媒性分子】 is a molecule which has both a water-soluble part and a water-insoluble one.

水になじむ部位と水になじまない部位を併せ持つ分子

**Detergent** : 【洗剤】 is a water-soluble cleaning agent.

洗浄の際に用いる水溶性の化合物

**Escherichia coli** 【大腸菌】 is a bacteria found in intestine of the organisms. It is commonly used as a model organism in the laboratory.

バクテリアの一種で自然界では腸内に生息する。実験生物として研究室でよく使われている。

**Lipid** : 【脂質】 is a class of organic compounds that are fat, oil, or wax.

脂肪や油、蝋の有機化合物の総称

**Maillard reaction** : 【メイラード反応】 is a chemical reaction between an amino acid and a reducing sugar. It causes browning of food like bread.

アミノ酸と還元糖との反応であり、パンなどの食品の褐色着色を引き起こす

**nucleotides** 【核酸】 is a building block of DNA that are the information molecules .

DNAを構成する部品。DNAは次世代に受け継がれる物質。

**Phospholipid** : 【リン脂質】 is an organic compound combining hydrocarbons and phosphates. 炭化水素鎖とリン酸とが結合した有機化合物

**Vesicle** : 【ベシクル】 is a closed bilayer membrane composed of amphiphiles.

両親媒性分子がつくる袋状の二重膜

**Speaker: Grégoire DANGER**

**UMR CNRS 7345 Ionic and molecular interactions physics laboratory (P2IM)**

**Astrochemistry Group, Team "Spectrométries et Dynamique Moléculaire",**

**Laboratory "Physique des Interactions Ioniques et Moléculaires", UMR-CNRS 7345,**

**Centre Saint-Jérôme, case 252, Aix-Marseille University, 13397, Marseille, France,**

**gregoire.danger@univ-amu.fr, Group Website: <http://sites.univ-provence.fr/piim/-Astrochimie-.html>**

## From interstellar medium chemistry to prebiotic chemistry: organic matter evolution toward Life?

Understanding the chemical evolution of the organic matter in astrophysical environments gives us clues on the chemical composition of the organic matter that may have seeded primitive planets, and further on the origin of biochemical systems on Earth. The organic matter present in dense molecular clouds in the form of ice mantles at the surface of interstellar grains can evolve toward a complete planetary system. All along this evolution, new and more complex molecules are formed thanks to various energetic processes including UV irradiation and thermal effects. Small bodies of planetary systems (asteroids and comets) eventually serve as a reservoir of this organic matter and as vectors for its delivery at the surface of telluric planets such as the primitive Earth. Therefore, there is probably a link between the molecules contained in cometary or meteoritic grains, and the molecules present in interstellar grains of the primitive dense molecular cloud. Furthermore, at the surface of specific environment such as the primitive Earth environment, this organic matter could have taken a part in the development of a prebiotic chemistry, a chemistry that precedes the emergence of biochemical systems. During this presentation, based on experimental approaches developed in our laboratory, we will try to understand this chemical evolution and determine which chemical processes can take place in these astrophysical environments [1-4]. This will allow us to obtain a better understanding of the origin and the evolution of the matter that makes up the objects of our solar system. Finally, we develop an experimental approach for studying prebiotic chemical processes in terrestrial planets such as on the Earth [5-8]. These processes could then represent the first stage for the development of the chemistry of living organisms.

[1] G. Danger, F-R. Orthous-Daunay, P. de Marcellus, P. Modica, V. Vuitton, F. Duvernay, L. Le Sergeant d'Hendecourt, R. Thissen, and T. Chiavassa, *Geochimica & Cosmochimica Acta*, 2013, 118, 184-201.

[2] V. Vinogradoff, N. Fray, F. Duvernay, G. Briani, G. Danger, H. Cottin, P. Theulé and T. Chiavassa, *Astronomy and Astrophysics*, 2013, 551, A128.

[3] G. Danger, F. Duvernay, P. Theulé, F. Borget, and T. Chiavassa, *The Astrophysical Journal*, 2012, 756, 11.

[4] G. Danger, F. Borget, M. Chomat, F. Duvernay, P. Theulé, J-C Guillemin, L. Le Sergeant d'Hendecourt, T. Chiavassa. *Astronomy and Astrophysics*, 2011, 525, A30.

[5] G. Danger, A. Michaut, M. Bucchi, L. Boiteau, J. Canal, R. Plasson, and R. Pascal, *Angewandte Chemie International Edition*, 2013, 52, 611-614.

[6] G. Danger, R. Plasson, and R. Pascal, *Chemical Society Reviews*, 2012, 41, 5416-5429.

[7] G. Danger, R. Plasson, R. Pascal, *Astrobiology* 2010, 10, 651-552.

[8] G. Danger, L. Boiteau, H. Cottet, R. Pascal, *J. Am. Chem. Soc.* 2006, 128, 7412-7413.



## **SESSION II**

**SESSION FIELD**  
**MATERIALS SCIENCE**

**SESSION TITLE**  
**GRAPHENE, THE 'MIRACLE MATERIAL'**

## SESSION II

### MATERIALS SCIENCE

# Graphene the "miracle material"

---

**Chair: Erik DUJARDIN**  
**CEMES CNRS UPR 8011, TOULOUSE, Fr.**

#### I - Introduction

Graphene is a one atom-thick sheet of carbon atoms linked to each other in a honeycomb lattice. Graphite that makes pencil tips can be seen as a multiple stack of graphene sheets. For more than 25 years, graphene has been considered as a good candidate to create materials and devices with unique electronic properties. Physicists and chemists had known it for decades but it has remained elusive until André Geim et Konstantin Novoselov (Univ. Manchester, GB) isolated it and produced graphene so easily that a large community of physicists, material scientists and chemists did grab this new opportunity to actually explore, tailor and exploit the properties of graphene. Nowadays, more than 7000 new papers have been published each year (almost one per hour!). Thousands of scientists, dozens of companies around the world are scrutinizing Graphene's properties. Never before has a newly mastered material pervaded so fast into new high technology applications.

#### II - Content of talk

The two speakers of this session will address two important aspects of graphene science: (1) how to make it with a quality adapted to targeted scientific and technological objectives and (2) how to probe and master the properties of graphene, in particular its electronics properties. As an introduction, I will raise the following questions: What unique properties of graphene explain the exceptional interest this material has been attracting for a decade? What discoveries justify that so many research laboratories and companies are investing time and effort on Graphene? Will graphene be up to the challenges and promises that society, researchers, industrials and politicians associate to it? After some general contextual description of graphene, we will focus on a presentation of a brief state of the art and a list of challenges regarding the production, characterization and exploitation of graphene.

#### III - Conclusions

After this abridged overview of graphene science in 2014, the two talks will give a more in depth view of graphene synthesis and graphene physics.

#### IV - References

Graphene, a 2D dream coming true. C. Soldano, A. Mahmood, E. Dujardin. Carbon, 2010, 48, 2127-2150.

**Speaker: Masashi SHIRAISHI**  
**Kyoto University**

#### I - Introduction

Carbon has some allotropes, for example, diamond and graphite. Diamond is loved as a costly and beautiful jewel, and it is used as a heat conductor and a cutting material in an industrial application. Graphite is known to be good at lithium intercalation and then is used as a negative electrode in a secondary ion battery. They have been studied and used in various fields, but it was thought by some people that study on carbon-related materials was comparatively out of date. However, this prejudice was suddenly broken in 1985 by a discovery



of fullerene,  $C_{60}$  [1]. Fullerene is a new carbon allotrope and possesses a spherical structure. The discovery opened a door for a frontier of nano-carbon science, and the discoverers were awarded the Nobel Prize in Chemistry in 1996. After the discovery, the field of nano-carbon science has rapidly grown, and carbon nanotube of which structure is tubular and of which wall consists only of carbon hexagons, as the second family of nano-carbon materials [2]. The biggest impact in nano-carbon science comes in 2004, i.e., the discovery of graphene [3]. Graphene has a 2-dimensional structure and consists of

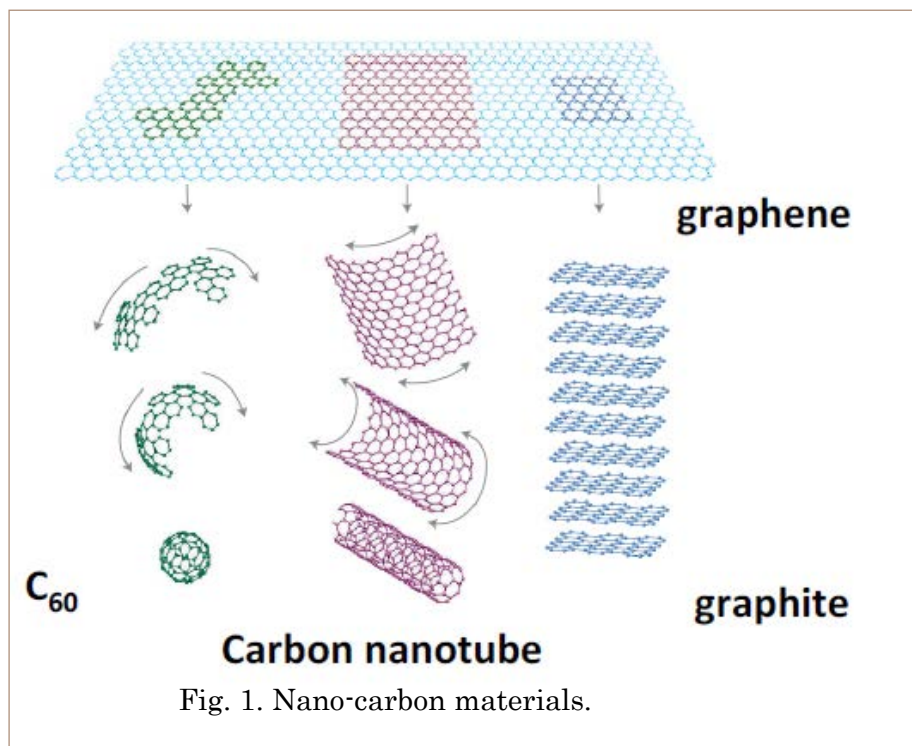


Fig. 1. Nano-carbon materials.

of carbon hexagons as carbon nanotube has. Graphene attracts tremendous attention from theoretical, experimental and application-based points of views, and the Nobel Prize in Physics was given to this discovery in 2010. The purpose of this presentation is to explain why graphene is called as a miracle material and how the graphene research will make progress.

## II - Why is graphene a miracle material?

It sounds somewhat surprising that there is relativistic quantum physics in graphene. Whereas the Newton equation describes the motion of matters in classical physics, the Schroedinger equation does in quantum physics. These equations are equations in a 3-dimensional space. Since time and space are equivalent in relativistic quantum physics, the Schroedinger equation is replaced by the Dirac equation, which consists of the 4(=3+1)-dimensional components. This equation can describe, for example, a motion of massless particles such as photons or neutrinos within a so-called standard model. The notable is that the motion of electrons in graphene is approximately equivalent to that of neutrinos, i.e., the equation of motion for electrons in graphene is approximately same as that of neutrinos. Relativistic quantum physics becomes apparent when a velocity of motion is close to the light velocity, and usually, a huge accelerator is necessary for investigating relativistic quantum physics. However, surprisingly, relativistic quantum physics apparently appears even in a condensed matter, graphene, which is the reason why graphene is regarded as a miracle material.

Because of the above-mentioned reasons, tremendous attention has been garnered after 2004, and a number of scientific papers related with graphene dramatically increased (see Fig. 2), and for example, a number of scientific papers in 2012, of which title includes “graphene”, is ca. 7000, i.e., roughly 20 papers per day.

## III - Which kind of future is expected?

By now, a wide variety of possible application has been proposed and investigated by using graphene: (1)

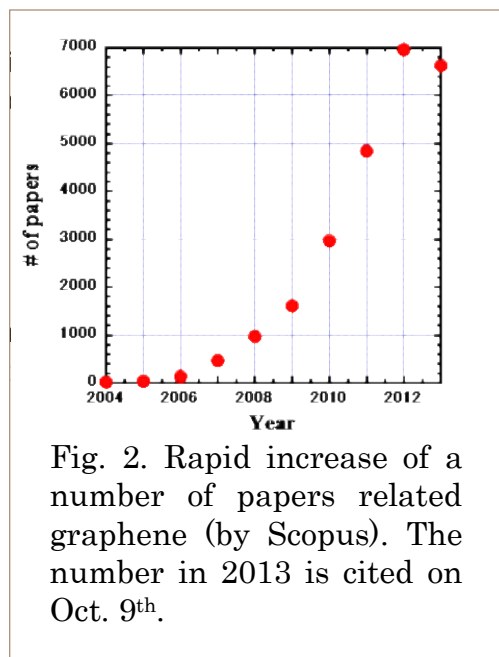


Fig. 2. Rapid increase of a number of papers related graphene (by Scopus). The number in 2013 is cited on Oct. 9<sup>th</sup>.

transparent electrode [4], (2) high-frequency device [5], (3) spintronics device [6], and so on. Here, I show three important research issues using graphene.

As for (1), large area (ca. 30 inch) graphene was synthesized and applied for transparent electrodes for touch panel application. Since the conventional transparent electrode (tin-doped indium oxide: ITO) includes a minor metal, indium, it is requested that ITO is replaced to the other ubiquitous materials. Since graphene consists only of carbon, this fulfills this request. High frequency devices are quite important for wireless broadband networks, and IBM demonstrated 100-GHz operation of a graphene device. Spintronics using graphene is also attracting tremendous attention, because pure spin current can be propagated in graphene [6,7]. Pure spin current is a flow of spin angular momentum without a charge flow, and is an ideally energy-dissipationless current, enabling ultra low energy consumption information propagation and calculation.

#### IV - Conclusion

As presented, graphene possesses bright future for both basic science and various applications, since graphene can break a present limit of technologies. For more detail, for example, see ref. [8].

#### V - References

[1] H.W. Kroto et al., Nature 318, 162 (1985). [2] S. Iijima, Nature 354, 56 (1991). [3] K. Novoselov et al., Science 306, 666 (2004). [4] S. Bae et al., Nature Nanotech. 5, 574 (2010). [5] Y.-M. Lin, Science 327, 662 (2010). [6] N. Tombros et al., Nature 448, 571 (2007). [7] Z. Tang, M. Shiraishi et al., Phys. Rev. B87, 140401(R), 2013. [8] M. Ruemmel, M. Shiraishi, S. Roche, G. Cuniberti et al., Adv. Mat. 23, 4471 (2011).

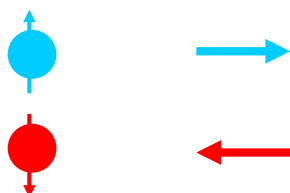
### 《Graphene, the “miracle material”》 Glossary

**Standard model** : 【標準模型】 There are 4 interactions in nature: (1) electromagnetic interaction, (2) strong interaction, (3) weak interaction, and (4) gravitational interaction. The electromagnetic interaction is an interaction that an electron is affected by electric and magnetic fields. The strong interaction is an interaction that, for example, a neutron and a positron affect each other, i.e., that nucleons in nuclei are affected. The weak interaction is an interaction that elementary particles such as quarks are affected (an elementary particle cannot be divided into some parts and does not have a domain. Electron, photon, quark and neutrino are elementary particles). The standard model unifies these 3 interactions under one equation. The Higgs particle, of which prediction and discovery was awarded for Nobel prize in Physics (2013), gives mass to particles (precisely fermions) in this model scheme. Within this model scheme, neutrino is massless, whereas experiments proved it is massive. Hence, an expansion of the standard model is necessary, which is one of the next targets in elementary particle physics. The unification of gravity has not been done, which is also an important target.

**Neutrino** : 【ニュートリノ】 Neutrino is one of elementary particles. It is chargeless, and called as lepton. Wolfgang Pauli predicted it and Enrico Fermi named it. Within the standard model scheme, it is theoretically massless. However, Masatoshi Koshiba experimentally proved that it is massive.

**Relativistic quantum physics** : 【相対論的量子論】 Quantum physics is regarded to have opened the door for modern physics. Here, for example, energies are quantized, which is completely different in classical physics. Relativity includes special relativity and general relativity, and one of the most important features in relativity is that time and space are equivalent. Quantum physics that includes special relativity is called as relativistic quantum physics, and equation of motion in relativistic quantum physics is 4-dimensional because of the equivalency of time and space.

**Pure spin current** : 【純スピンの流】 A flow of spin angular momentum without a charge flow. The schematic image is shown below. Electron possesses up- or down-spins. When we assume that one up-spin goes to the right and one down-spin goes to the left, there is no net charge flow because one electron goes to the right and the other electron goes to the left ( $1-1=0$ ). Here, because of the time reversal symmetry, the down-spin that goes to the left is equivalent to the up-spin that goes to the right. This may be confusing. Let's take a video of the above-mentioned motion of spins. When the time flow is reversed, the direction of the motion is also reversed. But in addition to the direction of motion, the direction of spin is also reversed (the detailed theory is not described here). So, the total number of up spin that goes to the right is 2 (not 1).



An image of pure spin current. Solid circles show electrons (charges) and arrows in the circles show the direction of spins (up or down). The other arrows show the direction of motion.

**Allotrope** : 【同素体】 Allotropes are different structural modifications of an element. Graphene, fullerene (C<sub>60</sub>), carbon nanotube, charcoal, graphite, and diamond are all allotropes of carbon.

**Newton equations (of motion)** : 【ニュートンの運動方程式】 Newton equations of motion are equations that describe the behavior of a macroscopic physical system in terms of its motion as a function of time. Motion of airplanes, balls, mechanical machines and macroscopic physical systems can be predicted by using the Newton equations of motions.

**Schrodinger equation** : 【シュレーディンガー方程式】 In quantum mechanics, the Schrödinger equation is a partial differential equation that describes how the quantum state of some physical system changes with time. The equation describes the behavior of electrons and atoms (microscopic).

**Dirac equation** : 【ディラック方程式】 The Dirac equation is a relativistic wave equation formulated by British physicist Paul Dirac. It describes fields corresponding to elementary spin- $\frac{1}{2}$  particles (such as the electron). The Dirac equation is consistent with both the principles of quantum mechanics and the theory of special relativity, and was the first theory to account fully for relativity in the context of quantum mechanics.

### **The Surface Science of Truly 2D Materials**

In 2004, Physicists started the exploration of the intrinsic properties of two-dimensional (2D) materials, first by studying graphene, an atomically-thin sheet of carbon atoms arranged in a honeycomb lattice. Since then, the interest has broadened towards other disciplines, including Chemistry and Biology, and the study of other 2D materials – boron nitride, dichalcogenides, silicene, silica – has started. These objects introduced new paradigms, not only relying on their unique 2D-specific properties, but also deriving from their platform-like topography. This true in both basic and applied research perspectives.

Just because they expose flat surfaces to the outside world, 2D materials seem ideally suited to surface science studies. This approach, though, is not mainstream. I will show that, alongside the study of devices based on 2D materials, surface science has provided invaluable insights into the understanding and control of the preparation and properties of these materials, and offers great potential for manipulating their properties and giving them new ones.

I will illustrate this viewpoint by (i) addressing the rich heritage of surface science studies of the preparation of graphene on metals, (ii) evoking some very recent highlights in the preparation of other 2D systems on metals, (iii) and giving a partial panorama of the toolkit which surface science offers for engineering the properties of graphene and graphenebased hybrid systems.

# **SESSION III**

**SESSION FIELD**  
**EARTH SCIENCE/ENVIRONMENT**

**SESSION TITLE**  
**EARTHQUAKES AND ASSOCIATED RISKS**

# SESSION III

## Earth Science/Environment

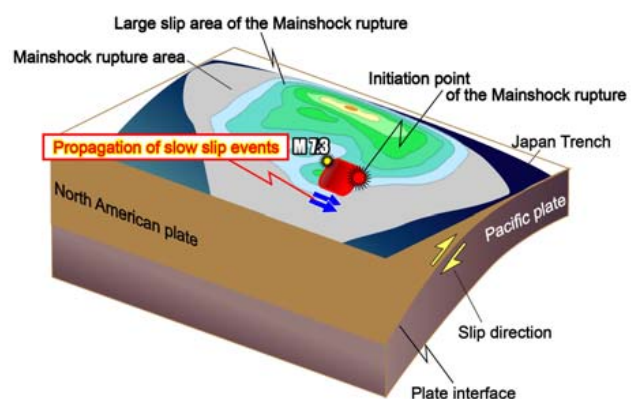
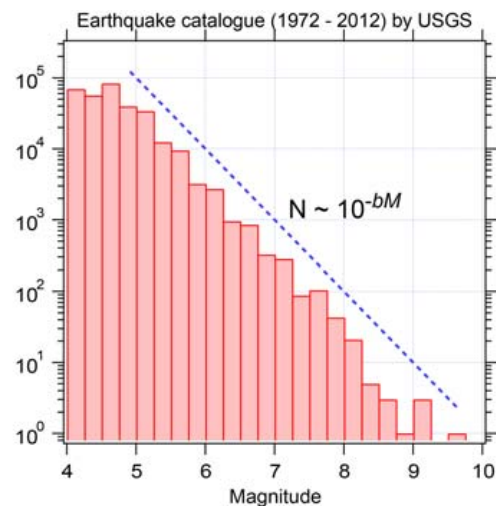
### Earthquakes and associated risks

**Chair: Aitaro KATO**  
**Earthquake Research Institute, The University of Tokyo**

Earthquake occurs as a result of shear slip instability along a fault embedded in the Earth's crust, which is composed of brittle rocks. During the dynamic rupture instability, fault surfaces slip with fast speed close to  $\sim 1.0$  m/s, resulting in radiation of seismic waves. Earthquake observations from micro earthquakes to giant earthquakes have revealed that shear slip instability in the Earth's interior encompass a much broader range of size and temporal scales. For example, frequency of earthquakes reduces with power law scaling of an increasing magnitude. While we have a huge number of small earthquakes, giant earthquakes are infrequent. These multi-scale behaviors of earthquakes are fundamental property, leading to complicated spatio-temporal evolutions of earthquake activity.

In the past decade, an unusual family of earthquake, which is called as "slow earthquake", has been extensively discovered around the world. Slow earthquakes occur as a shear slip event along tectonic fault that hosts ordinary earthquake, but the slip speed is much slower than an ordinary earthquake. Slow earthquakes are mostly located on the shallower and deeper extensions of major rupture areas of giant earthquakes. This means that slow earthquakes will increase stress on the major rupture areas. Thus, it has been keenly discussed about interaction between slow earthquakes and ordinary earthquakes. Prior to the 2011 Mw 9.0 Tohoku earthquake in Japan, seismic and geodetic measurements provide evidence for the propagation of slow slip events toward the Mw 9.0 epicenter. The slow slip events may have caused stress loading onto the prospective hypocenter of the mainshock and prompted the initiation of unstable dynamic rupture. Other recent studies show that most large earthquakes on plate interfaces were preceded by a phase of increased seismic activity, for which a possible mechanism is the slow slip.

In this session, we would like to discuss earthquakes and the associated risks in the viewpoints of (1) diversity of earthquakes, (2) earthquake mechanics based on laboratory experiments, and (3) disaster risk assessment from engineering and scientific approaches.





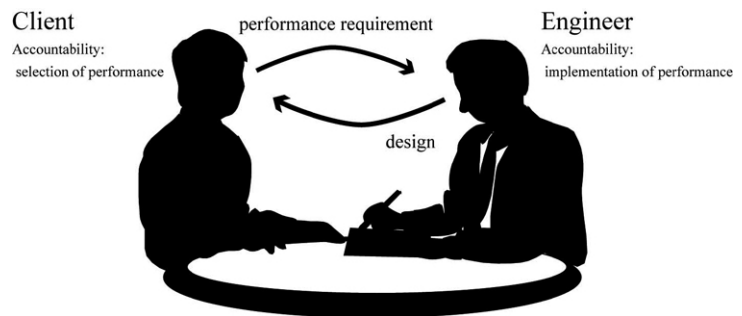
## I - Introduction

In the last decade, we experienced huge natural disasters due to earthquake, flood, volcanic explosion, landslide, etc. The 2004 Sumatra-Andaman earthquake caused a huge tsunami, and it killed more than 220 thousand people living in the coastal area of Indian ocean. 2008 Wenchuan and 2010 Haiti earthquakes directly hit inland areas, and caused a large amount of victims due to ground motions. The 2011 off the Pacific coast of Tohoku earthquake hit the eastern part of mainland Japan, and caused a huge tsunami that killed more than ten thousand people. Japanese government estimates 16.9 trillion JPY economic losses associated with the earthquake disaster.

Disaster risk is evaluated from occurrence of hazard and vulnerability of human society. In order to reduce the risk, government encourages the vulnerability improvement, such as structure retrofiting, evacuation training, etc. From both science and engineering points of view, I introduce the recent disaster risk assessment, and interesting research topics in this field.

## II - Seismic design concept

In a classical seismic design, engineers just follow a design specification, which contains a detail procedure to check seismic desistance of target structures. Recently, performance-based design has been applied to the seismic design. The performance depends on importance of the target structure, and is defined by a set 1) how it damages and 2) how frequent the seismic load excites it, e.g., “safety” under “rare” seismic event, “functional” under “frequent” event. Client provides the performance that is determined from cost, benefit, social situation, etc. Engineer designs the target structure as satisfying the performance. They owe different accountabilities, selection of the performance for client and implementation of the performance for engineer. In the performance-based design, the natural maximum seismic event is not essential. The logic, cost and accountability for the selected performance have a priority.

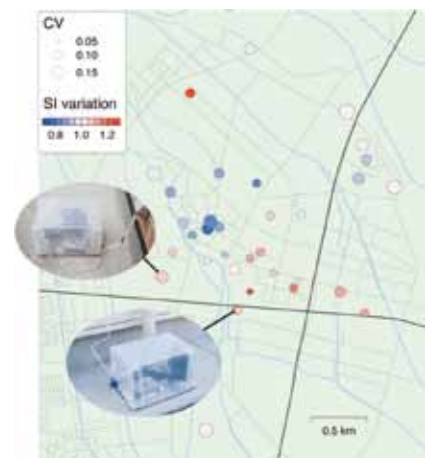


## III - Probabilistic Seismic Hazard Analysis (PSHA)

The cost consists of initial construction cost, maintenance cost, and also total loss due to earthquake disaster. The loss is usually estimated from fragility of the structure and probabilistic seismic hazard. Seismic hazard map is a typical output of PSHA as the intermediate products. PSHA is based on a probability of earthquake occurrence, and a variation on seismic wave propagations. The latter variation comes from a probability model of amplitude decays from seismic source, and a spatial difference on ground amplification.

## IV -Variation of Ground Amplification

Local geology controls the ground amplification qualitatively, and it causes the spatial differences. In current PSHA, it is usually modeled by deterministic variables. We focus on the variation characteristics on the ground amplification based on the innovative measurement. In the downtown, where there is a large potential of earthquake disaster, the dense measurement of ground motion has not been performed. We developed an advanced system for very dense seismic array observation, and installed it in Furukawa district, Japan, which was the damaged area during the 2011 Tohoku earthquake (Goto et al., 2011). It captures more than 500



events, and reveals the spatial and also site-specific variations. For variation modeling, we should connect the variation characteristics to spatial inhomogeneities of underground structure. I've developed physics-based decomposition of the ground amplification, and it enables to model arbitrary response as a superposition of simple states. We apply it to the variation modeling as a stochastic superposition.

## **V -Conclusion**

In risk assessment, scientific knowledge has been put to practical use. On the other hand, scientific innovation, such as variation modeling and convinced mechanism, for logical discussion between client and engineer is still in progress.

## **VI -References**

1. Goto, H., et al., "Earthquake source and ground motion characteristics in eastern Japan during the 2011 off the Pacific coast of Tohoku earthquake", Journal of JSCE, 1(2013), 329-342.
2. Goto, H., et al., "Very dense seismic array observations in Furukawa district, Japan", Seism. Res. Lett., 83(2011), 765-774.
3. Goto, H., "Series expansion of complex ground amplifications by a sequence of simple transfer functions", Earthquake Engng. Struct. Dyn., submitted.



**the 2011 off the Pacific coast of Tohoku earthquake** : 【2011年東北地方太平洋沖地震】 is an earthquake occurred in March 2011 along the plate boundary between the subducting Pacific plate and the north-American plate, caused severe tsunami damages along eastern coast of the mainland Japan.

**Crust** : 【地殻】 is the outermost layer of the Earth. Crust is very thin in comparison with the underlying mantle and core. The thickness of crust is only about 8 km under the oceans (oceanic crust) and about 35 km under the continents (continental crust). The crust is brittle enough to produce earthquakes.

**CV** : 【変動係数】 (Coefficient of Variation) is a normalized measure of variation, defined as a ratio of standard deviation to a mean.

**Deep-Focus earthquake** : 【深発地震】 Earthquakes occurring within the 400-700km depth window are termed deep-focus earthquakes and are systematically associated with subduction of tectonic plates.

**Disaster risk** : 【災害リスク】 is a degree of disaster effectiveness, defined by natural hazard multiplying vulnerability of human society.

ハザードと社会の脆弱性の掛け合わせとして定義される災害の程度を表す尺度.

**Dislocation** : 【転位】 In materials science, a dislocation is a crystallographic defect, or irregularity, within a crystal structure.

**Fault** : 【断層】 is a fracture along which the blocks of crust on either side have moved relative to one another parallel to the fracture.

**Ground amplification** : 【地盤増幅率】 is a ratio between input and surface ground motions. It depends on geology and stiffness of soils. Damage spots appear due to the spatial difference during the earthquake disaster.

**Ground motion** : 【地震動】 is a ground surface shaking due to seismic wave radiated from earthquake source.

**Gutenberg-Richter's law** : 【ゲーテンベルグ・リヒター則】 In seismology, the Gutenberg-Richter law expresses the relationship between the magnitude and total number of earthquakes in any given region and time period of *at least* that magnitude.

**Magnitude** : 【マグニチュード】 is a fundamental measure of the size of an earthquake in terms of the energy released during the slip.

**Olivine** : 【カンラン石】 The mineral olivine (when of gem quality, also called peridot) is a magnesium iron silicate with the formula  $(Mg^{+2}, Fe^{+2})_2SiO_4$ . Olivine and high pressure structural variants constitute over 50% of the Earth's upper mantle, and olivine is one of the Earth's most common minerals by volume.

**Omori's law** : 【余震の大森公式】 Omori's law, or more correctly the modified Omori's law, is an empirical relation for the temporal decay of aftershock rates.

**Performance-based design** : 【性能設計】 is a type of engineering design, defining a target performance under an external load. In seismic design, the performance is usually defined by a state after the earthquake loading.

外力に応じて性能を規定し、性能を満足することを要求する設計法

**PSHA** : 【地震ハザード評価】(Probabilistic Seismic Hazard Analysis) is a probabilistic approach to estimate a seismic hazard.

**Seismic array observation** : 【地震アレー観測】 is a system of ground motion measurement by spatially distributing seismometers.

**Slab** : 【スラブ】 In geology, a slab is the portion of a tectonic plate that is being subducted.

**Slip** : 【滑り】 is the relative displacement of formerly adjacent points on opposite sides of a fault.

**Slow earthquake** : 【ゆっくり地震】 is slow energy release process along a fault, of which duration is significantly longer than one of ordinary earthquake. For example, slow-slip events with magnitude ~ 6.0 continue for days to months.

**Spectral intensity** : 【SI 値】 is a one of the ground motion indexes, representing an effectiveness to the structure response. SI is better correlation with the structure damages. 地震被害と相関が高いとされる地震動の強さ指標の1つ。日本では都市ガスの供給停止の判断に利用されている。

**Stress** : 【応力】 is the force per unit area acting on a plane within a body.

**Superplasticity** : 【超塑性】 In materials science, superplasticity is a state in which solid crystalline material is deformed well beyond its usual breaking point, usually over about 200% during tensile deformation. Examples of superplastic materials are some fine-grained metals and ceramics.

**Tectonic Plate** : 【プレート】 is the moving outermost layer of the Earth. There are eight major plates in the Earth. The speed of lateral relative movements of the plates ranges from 1 to 25 cm/year. Each plate is composed of crust and upper most mantle.

## Deep focus earthquake analogs recorded at high pressure and temperature in the laboratory

### I - Introduction

The largest deep earthquake ever recorded happened on May 24th 2013. It was of a magnitude  $M_w=8.3$  and happened 620km deep below the earth surface, under the sea of Okhotsk (1). While the existence of deep earthquakes have been known since the 1920's (2-3), the essential mechanical process responsible for them is still poorly understood and remained one of the outstanding unsolved problems of geophysics and rock mechanics. Indeed, deep focus earthquake occur in an environment fundamentally different from that of shallow (<100 km) earthquakes (4), nowadays relatively well understood on the basis of theories relying on the properties of fracture, coalescing cracks and friction (5-6). As pressure and temperature increase with depth however, intra crystalline plasticity starts to dominate the deformation regime so that rocks yield by plastic flow rather than by brittle fracturing (6).

### II - Content of talk

Olivine phase transitions have provided an attractive alternative mechanism for deep focus earthquakes (7-9). Indeed, the Earth mantle transition zone (410-700km) is the locus of the two successive polymorphic transitions ( $\alpha \rightarrow \beta$  and  $\beta \rightarrow \gamma$ ) of olivine, the most abundant upper mantle mineral. Such scenario, however, runs into the conceptual barrier of initiating failure in a pressure (P) and temperature (T) regime where deviatoric stress ( $\Delta\sigma$ ) relaxation is expected to be achieved through plastic flow. Here, we performed laboratory deformation experiments on Germanium olivine ( $Mg_2GeO_4$ ) under differential stress at high pressure ( $P=2-5GPa$ ) and within a narrow temperature range ( $T=1000-1250K$ ). We find that fractures nucleate at the onset of the olivine to spinel transition. These fractures propagate dynamically (i.e. at a non-negligible fraction of the shear wave velocity) so that intense acoustic emissions are generated. Similar to deep-focus earthquakes, these acoustic emissions arise from pure shear sources, and obey the Gutenberg-Richter law without following Omori's law. Microstructural observations prove that dynamic weakening likely involves superplasticity of the nanocrystalline spinel reaction product at seismic strain rates.

### III - Conclusions

Although in our experiments the absolute stress value remains high compared to stresses expected within the cold core of subducted slabs (10), the observed stress drops are broadly consistent with those calculated for deep earthquakes (4). Constant differential stress conditions at failure over a wide range of confinement (2-5GPa) strongly suggest that transformational faulting is largely independent of normal stress and thus involves non-frictional processes. We suggest that rupture nucleation is controlled by dislocation density and spinel nucleation kinetics, while propagation is controlled by superplastic flow. High stress and high dislocation density conditions can be met in a cold subducting slab full of metastable olivine (11), due to stress concentrations at the micro and mesoscopic scales because of buckling, folding, and/or inherited fractures (12). This is particularly true in the Tonga-Kermadec region for instance, for which the largest catalog of deep focus earthquake is available (4).

### IV - References

1. Ye L., Lay T., Kanamori H. and Koper K.D., Energy release of the 2013  $M_w8.3$  Sea of Okhotsk earthquake and deep slab stress heterogeneity, *Science*, 341, 1380-1384, 2013.
2. Turner H.H., On the arrival of earthquake waves at the antipodes and the measurement of the focal depth of an earthquake, *Mon. Roy. Astr. Soc. , Geophys. Suppl.*, 1, 1-13, 1922.
3. Wadati, K. 1928. Shallow and deep earthquakes. *Geophys. Afag.* 1 : 1 6 1 -202
4. C. Frohlich, *Deep Earthquakes*, Cambridge University Press, Cambridge, U. K., 574 pp., (2006).
5. J.D. Byerlee, Friction of Rocks. *Pure and Applied Geophysics*, 116, 586-602 (1978).
6. 4. M.S. Paterson, T-f. Wong, *Experimental rock deformation – the brittle field*. (Springer-Verlag, Berlin Heidelberg, 2005).

7. D.T. Griggs, D.W. Baker, The origin of deep-focus earthquakes, H. Mark, S. Fernbach Eds, (Interscience, New York 1969), pp. 23-42.
8. S. Kirby, Localized polymorphic phase transformations in high-pressure faults and applications to the physical mechanism of deep earthquakes. *Journal of Geophysical Research*, 92, 13789-13800 (1987).
9. Green, H.W., Burnley, P.C., 1989. A new self-organizing mechanism for deep-focus earthquakes. *Nature* 341, 733– 737.
10. Bina, C. R., S. Stein, F. C. Marton, and E. M. Van Ark, Implications of slab mineralogy for subduction dynamics, *Physics of the Earth and Planetary Interiors*, 127, 51-66, (2001).
11. Iidaka T and Suetsugu D, Seismological evidence for metastable olivine inside a subducting slab, *Nature*, 356, 593-595, (1992).
12. Myhill R., Slab buckling and its effect on the distributions and focal mechanisms of deep-focus earthquakes. *Geophysical Journal International*, ggs054 (2012).

## V - Glossary

- **Deep-Focus earthquake:** Earthquakes occurring within the 400-700km depth window are termed deep-focus earthquakes and are systematically associated with subduction zones.
- **Olivine:** The mineral olivine (when of gem quality, also called peridot) is a magnesium iron silicate with the formula  $(Mg^{+2}, Fe^{+2})_2SiO_4$ . Olivine and high pressure structural variants constitute over 50% of the Earth's upper mantle, and olivine is one of the Earth's most common minerals by volume.
- **Gutenberg-Richter's law:** In seismology, the Gutenberg–Richter law expresses the relationship between the magnitude and total number of earthquakes in any given region and time period of at least that magnitude.
- **Omori's law:** Omori's law, or more correctly the modified Omori's law, is an empirical relation for the temporal decay of aftershock rates.
- **Superplasticity:** In materials science, superplasticity is a state in which solid crystalline material is deformed well beyond its usual breaking point, usually over about 200% during tensile deformation. Examples of superplastic materials are some fine-grained metals and ceramics.
- **Slab:** In geology, a slab is the portion of a tectonic plate that is being subducted.
- **Dislocation:** In materials science, a dislocation is a crystallographic defect, or irregularity, within a crystal structure.

# **SESSION IV**

**SESSION FIELD**  
**MATHEMATICS/INFORMATICS**

**SESSION TITLE**  
**BAYESIAN STATISTICS**

## SESSION IV

### Mathematics/Informatics

### Bayesian Statistics

---

**Chair: Seiya IMOTO**  
*The Institute of Medical Science, The University of Tokyo*

Thomas Bayes was born in London in 1702 and died in 1761 leaving a note with a part of a proof of Bayes's theorem. In recent years, Bayes's theorem or Bayesian statistics has become a sound theoretical base for data analyses, control, prediction and discovery in various research fields including social science, engineering, life science and so on. In this section, after illustrating the essential idea of Bayesian statistics, we show some paradoxical examples, discuss the historical argument between the Bayesian and frequentist schools of thought, subjectivist around priors, and end with a few cutting edge real examples.

Bayesian statistics can be considered as a mathematical framework for updating existing knowledge of subject or parameter of interest by getting observational data. In Bayesian statistics, the knowledge of the parameter is supposed to be represented by a probability function called prior probability; for example we know the mean height of men is around 170cm but it varies depending on populations. The prior probability function of the parameter will be updated using the information of observed data by Bayes theorem; it achieves posterior probability of the parameter (updated knowledge by the data). In other words, the framework of Bayesian statistics allows us to integrate additional information (prior probability) with the information of the data represented by the likelihood function.

Getting the posterior probability function of the parameter of interest is a crucial task in data analysis from a Bayesian point of view. It contains high dimensional integral in continuous case or combinatorial summation in discrete case, and mainly two approaches have been proposed; exact and approximate computations. The former approach restricts data analysts to use limited types of prior probability functions but can later be relaxed. However, the computational cost of the former is much lighter than that of the later.

Toshio Ohnishi will present the first approach in the Bayesian model averaging that combines a lot of Bayesian statistical models and the problem of minimizing Bayes risk that measures the badness of statistical models. Michael Blum will present a problem in population genetics with the second approach. Finally we will discuss the applicability of Bayesian methods to big data like the genomic data used in Blum's talk, and compare them with data-only-methods.

**Speaker: Toshio OHNISHI**  
*Faculty of Economics, Kyushu University*

#### I - Introduction

Maximization of the likelihood and that of the Shannon entropy are two of the most famous principles in statistics. The former derives the well-known maximum likelihood estimator. The latter is applied to find the most "random" statistical model in the wake of the second law of thermodynamics. This paper reveals a notable relationship between the two principles, which is a generalization of the result in Ohnishi & Yanagimoto (2013). A Bayesian model assumes not only a sampling density function with an unknown parameter but also a prior density function for the unknown parameter, while frequentists' model assumes the former only. The sampling density function is a statistical model for mechanism behind a data. The unknown parameter to be estimated is also regarded as a random variable in a Bayesian model.

Prediction, or density estimation, is a generalization of parameter estimation. The true density function is estimated based on a data. The estimated density function is called a predictor.

A loss function is adopted to compare more than one predictor. It is a kind of "price" we have to pay when a predictor is different from the true density function. The performance of a predictor is assessed by the expected value of the loss function, which is called the Bayes risk in the case of a Bayesian model. Finding the best predictor is formulated as an optimization problem, i.e., minimization of the Bayes risk.

The Kullback-Leibler divergence, denoted by  $KL(q,p)$  is one of the fundamental quantities in statistics. Roughly speaking, it is the distance between the two density functions  $q$  and  $p$ . Unlike the Euclidean distance, it is asymmetrical, i.e.,  $KL(q,p) \neq KL(p,q)$ . Nevertheless, they appear as a pair in theoretical statistics, and are said to be dual to each other (Amari & Nagaoka, 2000).

We adopt dual Kullback-Leibler divergences  $KL(q,p)$  and  $KL(p,q)$  as loss functions, where  $q$  is a predictor and  $p$  is the true density function. They are called the  $e$ -and the  $m$ -divergence loss functions, respectively. This duality turns out to link the likelihood maximization and the Shannon entropy maximization.

This paper investigates Bayesian model averaging, which is to average a number of Bayesian models according to our belief. We index those Bayesian models by introducing a parameter  $\xi$ . The belief is represented by a density function  $h(\xi)$ . Bayesian model averaging can cover such situations that we often encounter in actual data analyses.

We investigate the Bayesian model averaging in the framework of prediction problem. Two optimization problems are formulated. One is under the  $e$ -divergence loss function, and the other is under the  $m$ -divergence loss function. Each of them consists of (1) the best predictor in the  $\xi$  th Bayesian model and (2) a weight function  $h(\xi)$ .

## II - Results in the $e$ -divergence loss case

A "geometric mean" of the best predictors with weight  $h(\xi)$  plays an important role in this section, which we call the  $e$ -mixture.

*Theorem 1. The following statements hold under the  $e$ -divergence.*

- (i) *The  $e$ -mixture is the solution to the Bayes risk minimization problem.*
- (ii) *The Bayes risk minimization is equivalent to maximization of the Shannon entropy under a constraint. Maximization of the likelihood with respect to a weight function  $h(\xi)$  leads to the worst prediction.*
- (iii) *Maximization of the minimum Bayes risk with respect to a weight function  $h(\xi)$  leads to a constant-risk prediction.*

The essence of the proof of Theorem 1(ii) is a "reverse" procedure of the Lagrange multiplier method. Note that the Lagrange multiplier method rewrites an optimization problem with a constraint into an equivalent optimization problem free of constraints.

## III - Results in the $m$ -divergence loss case

The roles of the likelihood maximization and the Shannon entropy maximization are reversed in the case of the  $m$  divergence loss function. An "arithmetic mean" of the best predictors with weight  $h(\xi)$  plays a key role, which we call the  $m$ -mixture.

*Theorem 2. The following statements hold under the  $m$ -divergence.*

- (i) *The  $m$ -mixture is the solution to the Bayes risk minimization problem.*
- (ii) *The Bayes risk minimization is equivalent to maximization of the likelihood under a constraint. Maximization of the Shannon entropy with respect to a weight function  $h(\xi)$  leads to the worst prediction.*
- (iii) *Maximization of the minimum Bayes risk with respect to a weight function  $h(\xi)$  leads to a constant-risk prediction.*

## IV - Conclusion

- Maximization of the likelihood and that of the Shannon entropy are dual to each other in the sense of the duality between the  $e$ -and the  $m$ -divergences.
- In each case maximization of the minimum risk leads to a constant-risk prediction.

## V - References

1. Amari, S-I. and Nagaoka, H. (2000). *Methods of Information Geometry*. American Mathematical Society, Load Island.
2. Hoeting, J.A., Madigan, D., Raftery, A.E. and Volinsky, C.T. (1999). Bayesian model averaging: a tutorial. *Statistical Science*, 14, 382-417.
3. Ohnishi, T. and Yanagimoto, T. (2013). Two fold structure of duality in Bayesian model averaging. *Journal of the Japan Statistical Society*, 43, 29-55.

### 《Bayesian Statistics》 Glossary

**Bayesian model** : 【Bayes モデル】 In Bayesian statistics we assume a prior density function in addition to a sampling density function. The former is a density function for the unknown parameter in the latter. We call a combination of these density functions a Bayesian model.

**Bayes risk** : 【Bayes リスク】 The expected value of a loss function, which should be minimized. The expectation is calculated with respect to a Bayesian model.

**Density function**: 【密度関数】 A probability density function is sometimes referred to simply as a density function.

**Duality**: 【双対性】 The Kullback-Leibler divergences  $KL(p, q)$  and  $KL(q, p)$  are said to be dual to each other.

**e-mixture**: 【e-混合】 A "geometric mean" of density functions. The e-mixture  $q_e$  of the densities  $p_1$  and  $p_2$  with weight  $(a, 1 - a)$  is defined by  $q_e \propto p_1^a p_2^{1-a}$ .

**Frequentists' model** : 【頻度主義のモデル】 We assume a probability density function with an unknown parameter in order to make an inference about a data. The assumed density is sometimes called frequentists' model in contrast to a Bayesian model.

**Kullback-Leibler divergence**: 【Kullback-Leibler ダイバージェンス】 A measure of discrepancy of two density functions. The Kullback-Leibler divergence from  $q$  to  $p$  is defined by  $KL(q, p) = \int q \log \frac{q}{p}$ . It is asymmetric, i.e.,  $KL(q, p) \neq KL(p, q)$ .

**Likelihood**: 【尤度】 A fundamental quantity in statistics. When a sampling density function  $p(y; \theta)$  is assumed for a data  $x$ , the likelihood is defined as  $p(x; \theta)$ . This is a measure of how the statistical model  $p(y; \theta)$  fits the data  $x$ . The well-known maximum likelihood estimator is derived as the value  $\theta$  maximizing the likelihood  $p(x; \theta)$ .

**Loss function**: 【損失関数】 A criterion by which we assess predictors. We adopt the dual loss functions, the e- and the m-divergence loss functions. When estimating the true density function  $p = p(y; \theta)$  by the predictor  $q = q(y|x)$ , these are expressed respectively as  $KL(q, p)$  and  $KL(p, q)$ .



***m*-mixture:** 【*m*-混合】 An "arithmetic" mean of density functions. The *m*-mixture  $q_m$  of the densities  $p_1$  and  $p_2$  with weight  $(a, 1 - a)$  is defined by  $q_m = ap_1 + (1 - a)p_2$ .

**Model averaging:** 【モデル平均】 Averaging a number of statistical models with a certain weight. Model averaging is an alternative to the model selection, which is to choose one statistical model among competing ones.

**Prediction problem:** 【予測問題】 Estimating an unknown true density function  $p(y; \theta)$  by a predictor  $q(y|x)$  based on the data  $x$ . This is a generalization of parameter estimation where we restrict ourselves within the predictors of the form  $p(y; \hat{\theta})$  with  $\hat{\theta} = \hat{\theta}(x)$  being an estimator.

**Predictor:** 【予測分布】 A density function by which we estimate an unknown true density function. It is a density function for a random variable  $y$  given a data  $x$ , and is denoted by  $q(y|x)$ .

**Prior and posterior density functions:** 【事前および事後密度関数】 Probability density functions corresponding to a prior and a posterior distribution, respectively. In Bayesian statistics a prior density is assumed to describe our prior belief about an unknown parameter in a sampling density function. A posterior density, which plays a key role in Bayesian statistics, is calculated by way of the Bayes theorem.

**Shannon entropy:** 【Shannon エントロピー】 A fundamental quantity in information theory. A measure of randomness of the density function  $p$ , which is defined by  $H[p] = - \int p \log p$ . Maximization of the Shannon entropy is employed to derive a sampling density function when small amount of information is available.

**Sampling density function:** 【標本の密度関数】 In both Frequentist' model and Bayesian model we assume a density function as mechanism behind a data. We call it a sampling density to distinguish it from a prior density function.

*Speaker: Michael BLUM*

*UMR 5525 Techniques de l'Ingénierie Médicale et de la Complexité - TIMC - IMAG*

### **Bayesian Principal Component Analysis for detecting genes involved in Darwinian selection**

Using large numbers of genomic markers, genome scans can reveal a proportion of loci that deviate from neutral expectations because they contribute to Darwinian selection. This prominent biological process results in greater fitness of individuals in their local habitats due to natural selection. Understanding the genomic architecture of adaptation in humans is crucial to understand how past selection impacted disease susceptibility in modern populations. Here, we introduce an original method that seeks for outlier genomic regions using Bayesian principal component analysis. Bayesian approaches for genome scans have the desirable feature that they can control for the false discovery rate. Compared to more traditional approaches that are based on indices of genetic differentiation between populations, Bayesian PCA is fully unsupervised and do not require populations to be defined in advance. Using simulated data as well as a dataset of worldwide human genetic variation, we show the potential of Bayesian PCA for performing genome scans.

# **SESSION V**

**SESSION FIELD**  
**PHYSICS AND ASTROPHYSICS**

**SESSION TITLE**  
**SUPERSOLIDITY AND QUANTUM PLASTICITY**

# SESSION V

## Physics and Astrophysics

### Supersolidity and quantum plasticity

---

**Chair: Christophe JOSSERAND**  
**UMR 7190 - Institut Jean d'Alembert**

#### I - Introduction

Superfluids and Bose-Einstein condensates exhibit quantum behavior at macroscopic scale. One of their striking properties is that their viscosity vanishes under certain conditions and thus that it can flow without dissipation. Since the half of the 20th centuries, the possibility of such property for solids has been questioned. Since 2004, this quest for supersolidity has been revived by experimental results on torsional oscillators, results that have been shown to be misleading recently, since elastic effects explain the experimental signal. Tracking supersolidity has also led to focus on the specific properties of solid at very low temperature: the so-called quantum plasticity. The goal of this session is to present this supersolid story.

#### II - Content of talk

I will introduce and discuss the superfluidity and some striking experiments. Then I will present the specific challenge of supersolidity. Two different specific session will then discuss recent results on the field.

#### III - Conclusions

Even if the supersolidity claimed in 2004 appears to be due to other effects, supersolids are now investigated in many other physical systems.

#### IV - References

A.F. Andreev and I.M. Lifshitz, Sov. Phys. JETP. 29, 1107 (1969). A.J. Leggett, Phys. Rev. Letters, 25, 1543 (1970). E. Kim and M.H.W. Chan, Nature (London) 427, 225 (2004). S. Sasaki, R. Ishiguro, F. Caupin, H. J. Maris, S. Balibar, Science 313, 1098 (2006). Glossary if necessary: Bose-Einstein condensate: atomic gases forming at low temperature a condensate; in that case a macroscopic part of the atoms can be described by the same quantum state. Superfluid: at very low temperature some fluid (in particular liquid Helium) undergo a transition under which their viscosity vanishes.

**Speaker: Daisuke TAKAHASHI**  
**Ashikaga Institute of Technology**

#### I - Introduction

In the last decade, after the discovery of putative supersolid behaviors in  $^4\text{He}$  in torsional oscillator (TO) experiments by Kim and Chan [1], lots of efforts have been devoted to uncover their origin. Anomalies of solid  $^4\text{He}$  have been found in TO responses, which indicate reduction of rotational inertia, (Nonclassical Rotational Inertia, NCRI), heat capacity [2], and elastic property with an increase of shear modulus [3]. TO and heat capacity results strongly support the emergence of macroscopic coherent state similar to superfluid, while the shear modulus is controversial. The increase in shear modulus is explained well by pinning of dislocations by  $^3\text{He}$  atoms contained in solid  $^4\text{He}$  samples as an impurity[3,4]. Kim and Chan have recently claimed that the NCRI of solid  $^4\text{He}$  formed in nanopores of a porous Vycor glass is absent [4]. This reinforces the scenario that the stiffening of solid  $^4\text{He}$  is the major cause of NCRI seen in many TO studies, because there seems no dislocation networks in solid formed in nanopores[4]. In order to elucidate the nature of NCRI, we perform TO measurements for solid  $^4\text{He}$ , with rotating

the whole setup (“DC” rotation). If solid  $^4\text{He}$  possesses a macroscopic quantum nature, DC rotation can generate superflow and its quantization, i.e. quantized vortices.

## II - Continuous (i.e. DC) Rotating Experiment

When a bucket containing superfluid rotates faster than some critical DC angular velocity, irrotational property of the superfluid is broken, and the whole superfluid starts to rotate with the bucket because of the formation of quantized vortex array. The number of vortices increases in proportion to the angular velocity. The existence of quantized vortex is in general a definite evidence of macroscopic quantum state[6]. Superimposing DC rotation onto apparatus measuring NCRI or shear modulus may reveal the quantum nature of solid  $^4\text{He}$ .

We simultaneously measured the resonant frequency of TO and shear modulus of bulk solid helium under DC rotation with angular velocities between 0 and 4 rad/s. The DC rotation substantially decreases NCRI in annular solid samples, while no DC rotation effect was seen in shear modulus [7]. This result strongly supports that any connection between NCRI and shear modulus is indirect. The change in NCRI under DC rotation is possibly attributed to an appearance of quantized circulation.

## III - Evidence of Quantization : Quantum oscillation

We currently study the effect of DC rotation on NCRI of composite of solid  $^4\text{He}$  confined in a porous Vycor glass (pore size: 6 nm) and bulk solid  $^4\text{He}$ . Depletion of NCRI is observed at much smaller rotation speed than bulk solid  $^4\text{He}$  does. The dependence of NCRI on angular velocity  $\Omega$  has a very intriguing oscillating structure, in which the oscillation becomes periodic when NCRI is plotted as a function of  $\Omega^{-1}$  (Fig. 1).

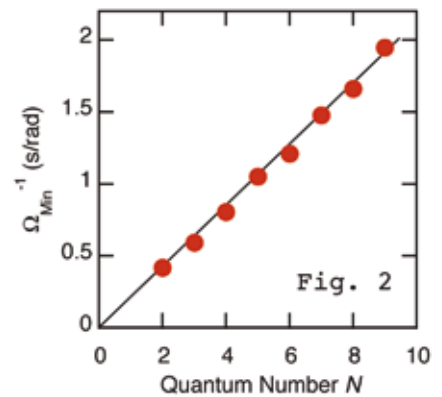
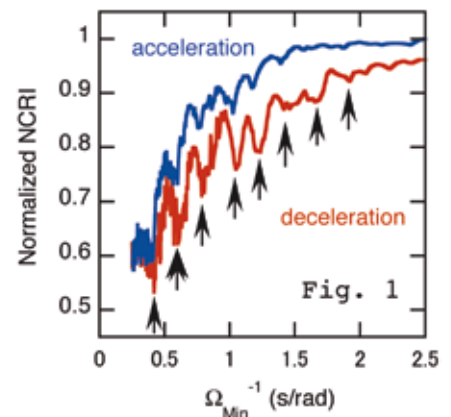
This behavior reminds us “quantum oscillation” phenomena observed in electrons in metals and semiconductors under magnetic field, such as de Haas van Alphen effect. The NCRI maxima and minima are periodically located very well. Here, each NCRI maximum or minimum could correspond to integer quantum number. In order to see the quantization, we number the NCRI minima 2 to 9. This number is referred to as Quantum Number  $N$ . We plot the locations of minima,  $\Omega_{\text{Min}}^{-1}$  against  $N$  are shown in Fig. 2. The  $\Omega_{\text{Min}}^{-1}$  is obviously proportional 0 to  $N$ . This result is the first clear observation of quantization phenomenon in solid  $^4\text{He}$  under DC rotation.

## IV - Conclusion

We have found that the TO response (NCRI) of solid  $^4\text{He}$  is sensitive to DC rotation, while the shear modulus is not. In composite solid samples containing porous Vycor we observed for the first time a signature of quantization phenomenon. This quantization appears as the quantum oscillation of  $\Omega^{-1}$ , which is reminiscent of the quantum oscillation in charged fermion systems. Although this oscillation needs further study, it gives a new aspect to physics of solid matter.

## V - References

- [1] E. Kim and M. H. W. Chan, Nature 427, 225 (2004); E. Kim and M. H. W. Chan, Science 405, 1941 (2004)
- [2] X. Lin, A. C. Clark, and M. H. W. Chan, Nature 449, 1025 (2007)
- [3] J. Day and J. Beamish, Nature 450, 853 (2007)
- [4] A. Haziot, X. Rojas, A. D. Fefferman, J. R. Beamish, S. Baliber, Phys. Rev. Lett. 110, 035301 (2013)
- [5] D. Y. Kim and M. H. W. Chan, Phys. Rev. Lett. 109, 155301 (2012)
- [6] “Quantum Liquids” : A. J. Legget, Oxford University Press (2006)
- [7] H. Choi, D. Takahashi, K. Kono, and E. Kim, Science 330 (2010); H. Choi, D. Takahashi, W. Choi, K. Kono, and E. Kim, Phys. Rev. Lett. 108, 105302 (2012); W. Choi, D. Takahashi, H. Choi, K. Kono, and E. Kim, Phys Rev. B. 86, 174505 (2012)



**Dislocation** : 【転位】 is a linear defect in a crystal structure. Strain onto material induces the motion of dislocation and therefore atoms around the dislocation are rearranged. The density of the dislocation mostly determines the stiffness of the metal.

**Helium3 ( $^3\text{He}$ )** : 【ヘリウム 3】 is the lightest noble gas. The atom consisting of one Proton, two Neutrons and electrons is neutral. The natural abundance is 0.00014% of Helium on the earth.

**Helium4 ( $^4\text{He}$ )** : 【ヘリウム 4】 is the simplest and light noble gas. The atom consisting of two Neutrons, Protons, and electrons is neutral. Because of its large zero point motion, Helium will remain liquid to absolute zero at atmosphere pressure. Helium solidifies above 25 bar below 4 K. Even in the solid phase, the position of atoms is not well localized at the lattice point by quantum fluctuation effect.

**Nanopore** : 【ナノ細穴】 is a hole the size of  $10^{-9}\text{m}$  which is almost 10 times larger than the atomic scale.

**Quantized vortex (vortices)** : 【量子渦】 is a topological defect existing in superfluids and superconductors. The number of the vortex is quantized, which increases discretely.

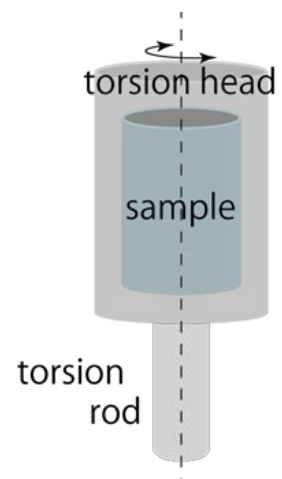
**Superflow** : 【超流動の流れ】 is a flow of superfluid.

**Superfluid** : 【超流動】 is a zero-viscosity fluid. It can pass through a tiny hole size of atomic scale. When Helium-4 is cooled down to 4.2 K, the macroscopic phase coherent state is developed, and then superfluidity appears. This state is considered to be due to Bose-Einstein condensation of helium atom.

**Shear modulus** : 【せん断弾性率】 is a quantity of the stiffness of materials, which is concerned with the deformation of a solid when the strain applies along parallel to the surface of the material.

**Torsional oscillator** : 【ねじれ振り子】 is a sort of pendulum. Schematic view of torsional oscillator is shown in the figure. Torsion head including sample space is supported the torsion rod. Torsion head swing back and forth around central axis by external force applied on the oscillator. The natural resonant frequency is  $\sqrt{K/I}$ , where K is modulus of rigidity of the bob and I is the rotational inertia of the head.

**Vycor glass** : 【バイコールガラス】 is a typical porous glass in which nanopores are formed as an interconnected network.



## I - Introduction

Superfluidity has a very special status within the states of matter: it is indeed a direct manifestation, at a macroscopic scale, of quantum physics. Usual fluid properties, like “how does it flow”, are deeply modified. Underlying this global behaviour, the quantum basis is to be found in the microscopic behaviour of its constituents, e.g. atoms: it is when they all behave like a single wave and become indistinguishable that superfluidity arises.

Beyond arising in liquids, like  $^4\text{He}$ , or gases, superfluidity can also occur in a solid. This is a priori more puzzling: atoms would then be at the same time arranged spatially with a definite pattern, *and* delocalized over all the pattern sites. Theoretically predicted in the 70s, quest for experimental observation of this state has been looked for mainly in solid  $^4\text{He}$ .

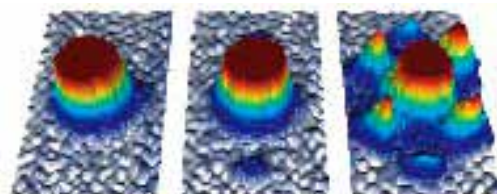
In parallel to “natural” many-body quantum systems such as  $^4\text{He}$  at low temperature or superconductors, atomic trapping and cooling techniques allow nowadays to engineer *artificial* many-body systems. Bose-Einstein condensation, achieved for the first time in 1995, arises when a very dilute atomic gas is cooled down to a temperature typically lower than  $10^{-6}$

K: atoms then all condense in the same wavefunction. As seen above, this forms a superfluid, as has been experimentally shown in particular by observation of vortices [1].

This system has several advantages. Excellent control over the system, combined with a large extension of the wavefunction, allows direct optical access to it. In addition, parameters become *tunable*: density, as well as interaction type and strengths, can be freely engineered. It becomes now possible to “simulate” various many body problems and phase diagrams. Recently, implementations of supersolidity have been investigated theoretically and experimentally (see e.g. [2] for a recent review), allowing an approach in a sense complementary to  $^4\text{He}$  experiments: it opens a window on the microscopic properties of the system and could help clearing out which of them are crucial for a supersolid to exist.

## II - Content of talk

The experiment I will present is realized with a  $^{87}\text{Rb}$  Bose-Einstein Condensate (BEC). This atomic species has normally weak interatomic interactions, but effective long-range interactions -needed to for supersolid ground state to replace the homogeneous ground state can be mediated via interaction with light. This is achieved by trapping the BEC in the center of a small (180 microns) optical cavity, tuned off-resonance near an atomic transition frequency. While shining a laser on the atoms, we have observed a cross-over between an homogeneous state of the BEC, and a self-organized state where atoms are arranged on a checkerboard pattern, while keeping their superfluidity. By recording the shadow of the atomic cloud on a CCD camera, one has direct access both to the shape of the atomic wavefunction and to the coherence between different pattern sites. We were able to reconstruct the superfluid/supersolid phase diagram in excellent agreement with *ab initio* theoretical calculations [3]. Further investigations elucidated the role of elementary excitations in this transition [4], in analogy to liquid  $^4\text{He}$ .



### **III - Conclusions**

This talk will allow to present a different (microscopic) approach to supersolidity, and a glimpse into the world of cold atom physics, which can form and explore very “pure” quantum states, illustrating elementary quantum behaviours or tackling the edges of our complex systems's understanding.

### **IV - References**

- [1] K. Madison, F. Chevy, V. Bretin and J. Dalibard, Phys. Rev. Lett. 86, p. 4443 (2001)
- [2] M. Boninsegni, N.V. Prokof'ev, Rev. Mod. Phys. 84, P. 759 (2012)
- [3] K. Baumann, C. Guerlin, F. Brennecke and T. Esslinger, Nature 464, p. 1301 (2010)
- [4] R. Mottl, F. Brennecke, R. Landig, T. Donner,



# **SESSION VI**

**SESSION FIELD**  
**LIFE/MEDICAL SCIENCE**

**SESSION TITLE**  
**PSYCHIATRIC DISORDERS/DEFINITIONS**  
**AND TREATMENTS**

# SESSION VI

## Life/Medical Science

### Psychiatric disorders: definitions and treatments

---

**Chair: Véronique DEROCHE-GAMONET**  
*Physiopathology of addiction, Inserm U862, Bordeaux, France*

The session deals with two major issues of psychiatry, i.e. definitions of disorders and treatment, the former impacting the latter, obviously.

Nosography is perpetually revised underlying the difficulty of producing absolute definitions of psychiatric disorders; one of the reasons being that diagnosis criteria are largely subjective.

Dr Takahashi and Mallet present neuroscience tools and methods, which when combined, allow obtaining objective psychobiological signatures of psychiatric disorders. Those signatures guide the choice of reliable targets and strategies for treatment. Dr Mallet exemplifies how a deeper knowledge of the neurobiology of Obsessive Compulsive Disorders leads to a rationale therapeutic application of Deep brain stimulation (DBS).

Dr Takahashi also introduces the concept of dimensional transnosographic approach of psychiatric disorders, echoing the recent Research Domain Criteria project (RDoC) of the NIMH. Distinct psychiatric disorders share common alterations in some key psychological dimensions, e.g. decision-making. Dr Takahashi shows how studying the neurobiology of impaired decision-making across neuropsychiatric disorders can improve our understanding of this pathological trait and its contribution to the concerned disorders, further specifying their definition. Finally, using the example of drug addiction, my own contribution will be to discuss why proper definitions of psychiatric disorders also condition the development of valid preclinical models and hence the identification of pertinent therapeutic targets, for a reliable translation to humans.

In summary, properly defining psychiatric disorders is neither obvious nor trivial, but instead an important and timely issue. Cutting-edge neuroscience tools and methods are now available, which create the conditions for a renewal of biological psychiatry.

#### I - References

Deroche-Gamonet, V., Belin, D., Piazza, P.V., 2004. Evidence for addiction-like behavior in the rat. *Science* 305, 1014–1017.

Kasanetz F\*, Deroche-Gamonet V\*, Berson N, Balado E, Lafourcade M, Manzoni O, Piazza PV. Transition to addiction is associated with a persistent impairment in synaptic plasticity. *Science*, 2010, 328(5986):1709-12. \*equal contribution.

Kasanetz F\*, Lafourcade M\*, Deroche-Gamonet V\*, Revest JM, Berson N, Balado E, Fiancette JF, Renault P, Piazza PV, Manzoni OJ. Prefrontal synaptic markers of cocaine addiction-like behavior in rats. *Mol Psychiatry*, 2013, 18(6):729-737. \*equal contribution.

Cannella N, Halbout B, Uhrig S, Evrard L, Corsi M, Corti C, Deroche-Gamonet V, Hansson AC, Spanagel R. The mGluR2/3 agonist LY379268 induced anti-reinstatement effects in rats exhibiting addiction-like behavior. *Neuropsychopharmacology*, 2013, Apr 29. doi: 10.1038/npp.2013.106.

Belin D, Berson N, Balado E, Piazza PV, Deroche-Gamonet V. High-novelty-preference rats are predisposed to compulsive cocaine self-administration. *Neuropsychopharmacology*, 2011, 36(3):569-79.

Belin D, Balado E, Piazza PV, Deroche-Gamonet V. Pattern of Intake and Drug Craving Predict the Development of Cocaine Addiction-like Behavior in Rats. *Biol Psychiatry*, 2009, 65(10): 863-8.

## II - Glossary of the session

- **Addiction:** Addiction is the continued repetition of a behavior despite adverse consequences, or a psychiatric disorder leading to such behaviors. Addictions can include drugs of abuse, food, sex, internet and gambling.
- **ADHD:** Attention-deficit/hyperactivity disorder (ADHD) is a psychiatric disorder. Typical symptoms of ADHD are difficulty in sustaining attention, hyperactivity and impulsive behavior.
- **Behavioral economics:** The field of economics that studies the effects of social, cognitive, and emotional factors on the economic decisions of individuals.
- **Biological psychiatry:** It is a school of psychiatric thought aims to understand mental disorders in terms of the biological function of the nervous system. Its detractors blame it for emphasizing the relationship between behavior and brain function, for searching exclusively for physical causes to mental illnesses and for focusing the treatment of mental disorders on medication.
- **Functional magnetic resonance imaging (fMRI):** A noninvasive method for imaging brain activity that uses imaging pulse sequences generated by an MRI scanner. The signal measured is caused by hemoglobin-based changes.
- **Neuroeconomics:** Neuroeconomics is an interdisciplinary field that combines research methods from neuroscience, experimental and behavioral economics, and cognitive and social psychology to explain human decision making.
- **Neurotransmitter:** Communication between neurons is achieved through release of small molecules called neurotransmitters from the pre-synaptic neuron. This chemical signal diffuses across a synaptic cleft to interact with specific receptors on the post-synaptic neuron in order to elicit a biochemical response.
- **Neurotransmitter receptors:** A receptor is a molecule usually found on the surface of a neuron that receives chemical signals from pre-synaptic neurons.
- **Neurotransmitter transporters:** A transporter located on the pre-synaptic neuron terminal reuptakes released neurotransmitter and terminates synaptic transmission.
- **NIMH:** “National Institute of Mental Health is part of the National Institutes of Health (NIH), a component of the U.S. Department of Health and Human Services. The NIMH Intramural division plans and conducts basic, clinical, and translational research to advance understanding of the diagnosis, causes, treatment, and prevention of mental disorders through the study of brain function and behavior.” (<http://www.nimh.nih.gov/index.shtml>).
- **Nosography:** Nosography is the systematic description of diseases. DSM (Diagnostic and Statistical Manual of Mental Disorders – American Psychiatric Association) and ICD (International Classification of Diseases – World Health Organization) are the two main classifications describing psychiatric disorders based on series of symptoms. “For each disorder, a set of diagnostic criteria indicate what symptoms must be present (and for how long), as well as symptoms, disorders, and conditions that must not be present to qualify for a particular diagnosis” (DSM, <http://www.psych.org/practice/dsm>).
- **Positron emission tomography (PET):** PET involves the use of an imaging device (PET scanner) and a radio-tracer that is injected into the patient’s bloodstream. Once the radiotracer accumulates in the body’s tissues and organs, its natural decay includes emission of positrons that react with electrons in the body. This reaction produces energy in the form of a pair of photons. The PET scanner, which is able to detect these photons, creates three-dimensional images that show how the radiotracer is distributed in the area of the body being studied.
- **Research Domain Criteria (RDoC):** “Strategy 1.4 of the NIMH Strategic Plan calls for the development, for research purposes, of new ways of classifying psychopathology based on dimensions of observable behavior and neurobiological measures. The Research Domain Criteria project (RDoC) has been launched by NIMH to

implement this strategy. In brief, the effort is to define basic dimensions of functioning (such as fear circuitry or working memory) to be studied across multiple units of analysis, from genes to neural circuits to behaviors, cutting across disorders as traditionally defined. The intent is to translate rapid progress in basic neurobiological and behavioral research to an improved integrative understanding of psychopathology and the development of new and/or optimally matched treatments for mental disorders.” (<http://www.nimh.nih.gov/research-priorities/rdoc/index.shtml>).

- **Synapse:** In the nervous system, a synapse is a structure that permits a neuron to pass an electrical or chemical signal to another neuron.
- **Transnosographic:** From nosography. It means “common to distinct diseases”. It is applied to describe psychological traits, symptoms, research strategies (e.g. RDoC).

**Speaker: Hidehiko TAKAHASHI**  
**Kyoto University**

Understanding and defining phenotype of psychiatric disorders.

### **I - Department of Psychiatry, Kyoto University Graduate School of Medicine**

Dysfunction of emotions and decision-making can be observed in various forms of psychiatric disorders. However, assessment and diagnosis of psychiatric disorders has been based on self-report or superficial observation of patients' behaviors. The topics about emotion and decision-making have been traditionally dealt with various discipline including humanities and social sciences. With the dissemination of non-invasive human neuroimaging techniques and the advancement of cognitive science and computational sciences, neuroscience studies focusing on emotions and decision-making have become established as a field of social neuroscience and computational neurosciences. The emerging fields of neuroscience will greatly contribute to clinical psychiatry. I will introduce our recent interdisciplinary neuroscience approach combining neuroimaging techniques (functional MRI; fMRI and positron emission tomography: PET), cognitive sciences, economics, pharmacology and engineering to assess, define and understand altered decision-making in neuropsychiatric disorders. An interdisciplinary approach will provide new perspectives for understanding the neurobiology of impaired decision-making in neuropsychiatric disorders and their drug development.

### **II - References**

Yamada M, Uddin LQ, Takahashi H, Kimura Y, Takahata K, Kousa R, Ikoma Y, Eguchi Y, Takano H, Ito H, Higuchi M, Suhara T. Superiority illusion arises from resting-state brain networks modulated by dopamine. *Proc Natl Acad Sci U S A.* (2013) 110(11):4363-7.

Takahashi H. Monoamines and assessment of risks. *Curr Opin Neurobiol* (2012)22(6):1062-7

Takahashi H, Takano H, Camerer C, Ideno T, Okubo S, Matsui H, Tamari Y, Takemura K, Arakawa R, Yamada M, Eguchi Y, Murai T, Okubo Y, Kato M, Ito H, Suhara T. Honesty mediates the relationship between serotonin and reaction to unfairness. *Proc Natl Acad Sci U S A* (2012) 109(11):4281-4284

Takahashi H, Fujie S, Camerer C, Arakawa R, Takano H, Kodaka F, Matsui H, Ideno T, Okubo S, Takemura K, Yamada M, Eguchi Y, Murai T, Okubo Y, Kato M, Ito H, Suhara T. Norepinephrine in the brain is associated with aversion to financial loss. *Mol Psychiatry* (2013) 18:3-4

Takahashi H, Matsui H, Camerer CF, Takano H, Kodaka F, Ideno T, Okubo S, Takemura K, Arakawa R, Eguchi Y, Murai T, Okubo Y, Kato M, Ito H, Suhara T. Dopamine D1 receptors and nonlinear probability weighting in risky choice. *J Neurosci* (2010) 30(49):16567-16572.

Takahashi H, Kato M, Matsuura M, Mobbs D, Suhara T, Okubo Y. When Your Gain is my Pain and Your Pain is my Gain: Neural Correlates of Envy and Schadenfreude. *Science* (2009) 323: 937-939

**Addiction** 【依存】 : Addiction is the continued repetition of a behavior despite adverse consequences, or a psychiatric disorder leading to such behaviors. Addictions can include addiction, food, sex, internet and gambling.

**ADHD** 【注意欠陥多動性障害】 : Attention-deficit/hyperactivity disorder (ADHD) is a psychiatric disorder. Typical symptoms of ADHD are difficulty in sustaining attention, hyperactivity and impulsive behavior.

**Behavioral economics** 【行動経済学】 : The field of economics that studies the effects of social, cognitive, and emotional factors on the economic decisions of individuals.

**Functional magnetic resonance imaging (fMRI)** 【機能的MRI】 : A noninvasive method for imaging brain activity that uses imaging pulse sequences generated by an MRI scanner. The signal measured is caused by hemoglobin-based changes.

**Neuroeconomics** 【神経経済学】 : Neuroeconomics is an interdisciplinary field that combines research methods from neuroscience, experimental and behavioral economics, and cognitive and social psychology to explain human decision making.

**Neurotransmitter** 【神経伝達物質】 : Communication between neurons is achieved through release of small molecules called neurotransmitters from the pre-synaptic neuron. This chemical signal diffuses across a synaptic cleft to interact with specific receptors on the post-synaptic neuron in order to elicit a biochemical response.

**Neurotransmitter receptors** 【神経伝達物質受容体】 : A receptor is a molecule usually found on the surface of a neuron that receives chemical signals from pre-synaptic neurons.

**Neurotransmitter transporters** 【神経伝達物質トランスポーター】 : A transporter located on the pre-synaptic neuron terminal reuptakes released neurotransmitter and terminates synaptic transmission.

**Positron emission tomography (PET)** 【陽電子放射断層撮影】 : PET involves the use of an imaging device (PET scanner) and a radiotracer that is injected into the patient's bloodstream. Once the radiotracer accumulates in the body's tissues and organs, its natural decay includes emission of positrons that react with electrons in the body. This reaction produces energy in the form of a pair of photons. The PET scanner, which is able to detect these photons, creates three-dimensional images that show how the radiotracer is distributed in the area of the body being studied.

**Synapse** 【シナプス】 : In the nervous system, a synapse is a structure that permits a neuron to pass an electrical or chemical signal to another neuron.

## **I - Introduction**

Deep brain stimulation (DBS) is able to target with precision specific cerebral networks, thus offering hope for severe and treatment refractory illnesses, as well as to investigate in the detail the subcortical bases.

## **II - Content of talk**

In obsessive-compulsive disorder (OCD), DBS is being tested at several nodes of a prefrontal–subcortical circuit, including the subthalamic nucleus (STN). Functional imaging studies of OCD patients have shown abnormal metabolic activity of the orbito-frontal and cingulate cortices, as well as of the anterior part of the striatum. In animal and human studies, these structures have been associated with performance-monitoring and more generally metacognitive processes, thus suggesting that metacognitive dysfunctions might be central to OCD leading to pathological doubt. In this conceptual framework of hyperactive distrust metacognitive mechanism in OCD, checking behaviour can be regarded as an ill-founded metacognitive strategy designed to restore confidence in the outcome of one's actions. Within the basal ganglia network, the STN could act a crucial part in this process regarding its role in the inhibitory control of behaviour. Moreover, anatomy and neuro-computational models of the basal ganglia show that this nucleus is in the position to implement cortical metacognitive control by increasing the threshold for decision.

## **III - Conclusions**

This framework has the advantage of providing a theoretical basis to the promising clinical results obtained for STN-DBS in severe resistant OCD. Bearing in mind this model, it can be postulated that DBS, by its action on STN, positively interferes with the neural mechanism underlying compulsive behaviour.

## **IV - References**

- Baunez, C., Yelnik, J., & Mallet, L. (2011). Six questions on the subthalamic nucleus: lessons from animal models and from stimulated patients. *Neuroscience*, 198, 193–204. doi:10.1016/j.neuroscience.2011.09.059
- Burbaud, P., Clair, A.-H., Langbour, N., Fernandez-Vidal, S., Goillandeau, M., Michelet, T., et al. (2013). Neuronal activity correlated with checking behaviour in the subthalamic nucleus of patients with obsessive-compulsive disorder. *Brain*, 136(Pt 1), 304–317. doi:10.1093/brain/aws306
- Chamberlain, S. R., Menzies, L., Hampshire, A., Suckling, J., Fineberg, N. A., del Campo, N., et al. (2008). Orbitofrontal dysfunction in patients with obsessive-compulsive disorder and their unaffected relatives. *Science*, 321(5887), 421–422. doi:10.1126/science.1154433
- Clair, A. H., N'Diaye, K., Baroukh, T., Pochon, J. B., M'Orgiève, M., Hantouche, E., et al. (2012). Excessive checking for non-anxiogenic stimuli in obsessive-compulsive disorder. *European Psychiatry*, 1–7. doi:10.1016/j.eurpsy.2012.11.003
- Figeé, M., Luigjes, J., Smolders, R., Valencia-Alfonso, C.-E., van Wingen, G., de Kwaasteniet, B., et al. (2013). Deep brain stimulation restores frontostriatal network activity in obsessive-compulsive disorder. *Nature Publishing Group*, 16(4), 386–387. doi:10.1038/nn.3344
- Haynes, W. I. A., & Mallet, L. (2010). High-frequency stimulation of deep brain structures in obsessive-compulsive disorder: the search for a valid circuit. *European Journal of Neuroscience*, 32(7), 1118–1127. doi:10.1111/j.1460-9568.2010.07418.x
- Hermans, D., Engelen, U., Grouwels, L., Joos, E., Lemmens, J., & Pieters, G. (2008). Cognitive confidence in obsessive-compulsive disorder: distrusting perception, attention and memory. *Behaviour Research and Therapy*, 46(1), 98–113. doi:10.1016/j.brat.2007.11.001
- Le Jeune, F., Vérin, M., N'Diaye, K., Drapier, D., Leray, E., Montcel, Du, S. T., et al. (2010). Decrease of prefrontal metabolism after subthalamic stimulation in obsessive-compulsive disorder: a positron emission tomography study. *Biol Psychiatry*, 68(11), 1016–1022.
- Mallet, L., Polosan, M., Jaafari, N., Baup, N., Welter, M. L., Fontaine, D., et al. (2008). Subthalamic nucleus

stimulation in severe obsessive-compulsive disorder. *New England Journal of Medicine*, 359(20), 2121–2134. doi:10.1056/NEJMoa0708514

Mallet, L., Schupbach, M., N'Diaye, K., Remy, P., Bardinet, E., Czernecki, V., et al. (2007). Stimulation of sub-territories of the subthalamic nucleus reveals its role in the integration of the emotional and motor aspects of behavior. *Proc Natl Acad Sci U S A*, 104(25), 10661–10666.

Welter, M. L., Burbaud, P., Fernandez-Vidal, S., Bardinet, E., Coste, J., Piallat, B., et al. (2011). Basal ganglia dysfunction in OCD: subthalamic neuronal activity correlates with symptoms severity and predicts high-frequency stimulation efficacy. *Transl Psychiatry*, 1, e5. doi:10.1038/tp.2011.5

## V - Glossary:

- **Basal ganglia:** group of subcortical grey nuclei located in the depth of the cerebral hemispheres, interconnected with the cerebral cortex, thalamus and brainstem, and associated with a variety of functions: motor control, cognition, emotions, and learning.
- **Deep Brain Stimulation:** DBS consists of stereotactic implantation of electrodes in deep brain structures. The electrodes are connected by a sub-cutaneous cable to an implantable electric stimulator enabling the application of high frequency (80-180Hz) current to the target structure. The effect of the stimulation is reversible and the various stimulation parameters (frequency, pulse width and voltage) are adjusted in order to obtain the best possible results in the absence of undesirable side-effects and low morbidity.
- **Metacognitive monitoring:** the ability to evaluate one's own cognitive functions.
- **Obsessive-Compulsive disorder:** anxiety disorder characterized by recurrent, unwanted thoughts (obsessions) and/or repetitive behaviors (compulsions). Repetitive behaviors such as handwashing, counting, checking, or cleaning are often performed with the hope of preventing obsessive thoughts or making them go away. Performing these so-called "rituals," however, provides only temporary relief, and not performing them markedly increases anxiety.
- **Stereotaxis:** relating to or denoting techniques for surgical treatment or scientific investigation that uses medical imaging to precisely locate in three dimensions an anatomical site to which a surgical instrument or a beam of radiation is directed.





# **SESSION VII**

**SESSION FIELD**  
**SOCIAL SCIENCES/HUMANITIES**

**SESSION TITLE**  
**HAPPINESS**

# SESSION VII

## Social Sciences/Humanities

### Happiness

---

*Chair: Claire ETCHEGARAY*  
*Institut de Recherches Philosophiques (Université Paris 10)*

#### I - Introduction

A basic contradiction lies at the core of philosophical research on happiness: on the one hand, this notion is indeterminate and on the other hand, it is indispensable. Admittedly, happiness stems from perfect satisfaction. But none of the particular desired objects could ever afford such satisfaction, termed in French “bonheur”, because this means complete well-being. Thus, we first recall the paradox of satisfaction with which any hedonism is faced. Satisfaction is temporary (if not precarious) because the desire itself seems to be renewed by pleasure or well-being. This is further complicated by the fact that what is satisfying in one way can be dissatisfying in another way. Nevertheless, happiness seems to be an indispensable concept for the theory of action. However incomplete the pursuit of happiness may be, it is taken for granted that an action is motivated by some intended good. Whatever this good, does it not bring happiness itself? But equating goodness with happiness is problematic too. One argument against it might be that moral goodness must be defined independently of any consideration of happiness. However even Kant, the most famous figure in the history of philosophy, who defended strong deontology, did not deny that a virtuous man must believe that he deserves happiness and so believe in the possibility of post-mortem recompense if there is a just Almighty.

#### II - Content of talk

This leads to different lines of enquiry in the philosophy of action and in moral philosophy. Taking moral philosophy first, we shall recall the debate between the deontological point of view and consequentialism<sup>1</sup>. One version of the latter is utilitarianism, i.e. the defence of utility maximization as a practical criterion. Yet recently, other options have been explored. “Virtue Ethics” argues that the moral end is neither acting out of moral duty, nor acting in order to obtain the greatest good (be it pleasure or profit, personal or collective), but that personal perfection which is an achievement of humanity in each self. The definition of happiness changes with these options. It is an imaginary reward motivating action but not virtue itself for the deontologist, an optimised benefit for the utilitarian, well-being as the realisation of the nature or the capacities of an agent for the philosopher promoting virtue ethics. In France, we have recently seen the defence of so-called “minimalist ethics” as a way of saving moral philosophy from its tendency (in the Western tradition) to be paternalistic. In such a view, morality does not consist in making oneself or others happy, but only in avoiding harming others (Ogden, 2007).

In all these approaches, researchers draw on the history of philosophy. Thus, one challenge presented by the readings of Aristotle in “Virtue Ethics” is to conceptualise the good life without subscribing to a straightforward and naïve naturalism. Another example can be found in the interpretation of Scottish philosophers (like Hutcheson, Hume and Smith), or the classical utilitarians (Bentham and Stuart Mill) in order to conceive of calculating good in a purely instrumental way.

Secondly, we shall turn to the question “how do we look for happiness?”. In part, the philosophy of action aims at questioning the rationality of deliberation, decision and action. But in addition, any current philosophical theory of action must include some theory of “weakness of the will” (akrasia in greek), i.e. it must account for the fact that sometimes, however desirable an action may be for us (even more desirable than any other in given circumstances) and however much we may believe that this is the action that we must perform, we do not do it.

<sup>1</sup> *Consequentialism and its Critics*, dir. Samuel Schaeffer, Oxford, Oxford University Press, 1988

### III - Conclusions

Finally, we shall consider two philosophical approaches that cross into other sciences and question notions of welfare and quality of life. In the philosophy of medicine, there is a certain French focus on the relationship between welfare and health, as well as on issues of biotechnological enhancement (Nordenfelt, 2001). In political philosophy, the “capabilities approach” claims that we need to seek institutional guarantees of the material conditions necessary for the development of human capabilities as the basis for some principles of justice, rather than founding the theory of just governance on subjective welfarism or on objective utilitarian measures of happiness (PIB, income, etc.) (Sen, 2009 and Nussbaum, 2011).

### IV - References

Lennart Nordenfelt, « On the Goals of Medicine, Health Enhancement and Social Welfare », in *Health Care Analyses*, 9, 1, 2001, pp. 15-23 ; *Action, Ability and Health. Essays in the Philosophy of Action and Welfare*, Dordrecht, Kluwer Academic Publisher, 2000, Fr. tr. of « Ability and Health » by Denis Forest and Marion Le Bidan in *Textes clés de philosophie de la médecine*, Paris, Vrin, 2012

Martha Nussbaum, *Creating Capabilities. The Human Development Approach*, Cambridge MA, Harvard University Press, 2011, Fr. tr. *Capabilités. Comment créer les conditions d'un monde plus juste ?*, Paris, Flammarion, 2012

Ruwen Ogien, *L'éthique aujourd'hui. Maximalistes et minimalistes*, Paris, Gallimard, 2007

Amartya Sen, *The Idea of Justice*, London, Penguin, 2009, Fr. tr. *L'idée de justice*, Paris, Champs Essais, 2010

### V - Glossary

- **Consequentialism**: a theory holding that any action is evaluated according to the results, and not to the nature, of the act or to the intention behind the act. One kind of consequentialism holds that the value of an action depends on the satisfaction procured by its results.
- **Deontologism**: a theory holding that the value of any action is that it performs or intends to perform what it has to perform according to any rational law or moral duty (worthing independently to any sensible pleasure or particular interest). In the history of philosophy, Immanuel Kant is the major figure in this approach.
- **Hedonism**: theory holding that the value of action is pleasure, or some kind of pleasure which is more constant, or less complicated by pain. In the history of philosophy, Epicurus is the major figure in this ethics.
- **Utilitarianism**: theory holding that the value of action is to maximize utility and thence happiness. As such, it does not only prescribe an ethics of pleasure (implying the regulation of pleasure) but also a rational calculation of the way to reach “the greatest good for the greatest number”. It is a kind of consequentialism.
- **Welfarism**: 1/ In moral philosophy, a theory which argues that the justificatory force of any moral reason is that it procures well-being, 2/ In social sciences and economics, any approach holding that social well-being is a political goal to be determined taking into account the expression of individual preferences.
- **Capabilities approach**: a theory, mainly held by Amartya Sen and Martha Nussbaum, that any social and political conception of justice must stem from reflection on the quality of life. Sen and Nussbaum denounce welfarism (in sense 2/), pointing out that painful conditions of life can lead to an adaptation of individual desires and preferences such that declarations of self-satisfaction can be in disaccordance with the actual quality of life. According to them, the economics of development need to define some fundamental conditions of the human good life, that is, define the conditions in which human capabilities can be developed.

### **I - Introduction**

The economics of happiness or happiness economics is a challenging and emerging field of research. Economists traditionally focused on objective and measurable concepts such as well being, income, wealth, health, etc. Since the late nineties economists (Easterlin, Frey, Oswald) have combined sociology, psychology and cognitive sciences' inputs and tried to tackle the subjective issue of happiness. The field has grown and used advanced methods to measure happiness.

### **II - Content of talk**

The main problem is to measure such a subjective concept: it is difficult to compare levels of happiness across individuals and across culture. However, despite this methodological difficulty, economists have demonstrated consistent patterns across time and countries. We shall review those patterns

The economics of happiness tries to resolve puzzles such as: the increasing income and yet non increasing happiness, the objective and positive effects of globalization and yet increased unhappiness linked to globalization, etc. This approach has also shed light on irrational behavior such as addictive behavior or excessive consumption.

### **III - References**

- Alesina, A., Di Tella, R. and MacCulloch, R. (2004). "Inequality and happiness: Are Europeans and Americans different?". *Journal of Public Economics*, 88, 2009–2042.
- Alpizar, F., Carlsson, F. and Johansson-Stenman, O. (2005). "How much do we care about absolute versus relative income and consumption?". *Journal of Economic Behavior and Organization*, 56, 405-421.
- Blanchflower, D.G. et Oswald, A.J. (2004). "Well-being over time in Britain and the USA". *Journal of Public Economics*, 88, 1359-1386.
- Clark, A.E., Etilé, F., Postel-Vinay, F., Senik, C., et Van der Straeten, K. (2005). Heterogeneity in reported well-being: Evidence from twelve European countries. *Economic Journal*, 115, C118-C132.
- Di Tella, R. et MacCulloch, R. (2006). Some uses of happiness data in economics. *Journal of Economic Perspectives*, 20, 25-46.
- Di Tella, R. MacCulloch, R. et Oswald, A.J. (2003). The macroeconomics of happiness. *Review of Economics and Statistics*, 85, 809–827.
- Easterlin R., 1974, « Does Economic Growth Improve the Human Lot ? Some Empirical Evidence », in P.A. David et M.W. Reder, eds, *Nations et Households in Economic Growth*, p 89-125, New-York, Academic Press.
- Easterlin R., 2001, « Income et Happiness : Towards a Unified Theory », *The Economic Journal*, 111, 465-484.
- Easterlin, Richard A. (2003). "Explaining Happiness", *Proceedings of the National Academy of Sciences*, Vol. 100, No. 19, September 16.
- Kahneman, D. et Krueger, A.B. (2006). Developments in the measurement of subjective wellbeing. *Journal of Economic Perspectives*, 22, 3-24.
- Kahneman, Daniel, Ed Diener, and Norbert Schwarz (1999). *Well-being: The Foundations of Hedonic Psychology* (New York: Russell Sage).
- Oswald, Andrew (1997). "Happiness and Economic Performance" . *The Economic Journal*, Vol. 107, No. 445, pp.1815–31.

## **I - Introduction**

What is the "happiness" for us who live in the modern society? In order to answer this question, I would like to think our personal happiness in consideration of the characteristic points of the present age, especially thinking how we regard the global environmental issues for our society. Almost five decades already passed, since such issues became to be shared socially. In the meantime, focusing on their social position there has been some turning points in a cycle of about 20 years. We can consider the first two decades (1970s-80s) as the 1<sup>st</sup> generation, the second (1990s-2000s) as the 2<sup>nd</sup> generation and now, namely the 20 years beginning from 2010 as the 3<sup>rd</sup> generation. This classification does not just depend on counting years, but corresponds with the change of subjective impression or consciousness of the environmental issues for our society. Roughly saying, we can characterize using simple keyword's, them for the 1<sup>st</sup> generation as COUNTER, for the 2<sup>nd</sup> as TREND and for the 3<sup>rd</sup> as NORMAL.

## **II - 1<sup>st</sup> Generation and 2<sup>nd</sup> Generation**

The 1<sup>st</sup> generation was the time of counter culture. The environmental pollution by industrialization and the destruction of nature by development getting more and more serious, the problem in the global level began to attract social interest in the beginning of 1970s. At that time, economic activities including urbanization were severely criticized as opposition to environmental protection. Indeed there was a rise of environmental awareness but it had a tendency to anti-power and anti-establishment and was never mainstream. The people who had an environmental intention were minority in the society to the last. While the enthusiastic minority sought after the lifestyle harmonized with nature in the 1<sup>st</sup> generation, being conscious of the environment no longer had any anti-power meaning but became to be main stream or trend in the 2<sup>nd</sup> generation. Global environmental issues achieved the position of main topics for politics and the consideration for them from industries to families. The people with ecological mind lived not in the countryside but in the urban area. The environmental protection seemed to get reconciled with economic activities, as it was symbolized in the case of hybrid cars.

What can these generations be considered as the theme of subjectivity? The environmental consciousness is essentially contrary to the economic activity, because the latter seeks for its own benefit in principle, while the former fundamentally tries to benefit the others, namely the other people we unconsciously oppress in daily consumption or the other nature which is different from humankind. Here is the opposition between self-interest or egoism and altruism, which is essential criteria for the subjective decision of behavior. The 1<sup>st</sup> generation tried to oppose to the selfish economic activity, and aimed at altruism. Although it seems that the 2<sup>nd</sup> generation succeeded in the mediation between the both sides, it exactly realized the complacency for the trend-oriented selfish desire. Such divided situation in the mind of the 2<sup>nd</sup> generation people might have promoted the absence of the subjectivity as a result.

## **III - 3<sup>rd</sup> Generation**

Félix Guattari's "*Les trois écologies* (the three ecologies)" (1989) is small but important in that it suggests the direction of the 3<sup>rd</sup> generation. In Guattari's view, we need to take account not just of the conventional kind of ecology, the "environmental ecology", for natural environment but of the "social ecology" and also the "mental ecology" in order to conquer the ecological unbalance with which our modern society is faced, and to establish the new sort of knowledge, "eco sophie", which should connect these three ecologies.

The three ecologies presented by Guattari could be applied to the three generations mentioned above. The 1<sup>st</sup> generation as COUNTER sometimes turned the back to human society, and intended to be just within nature so that it might be seen in the case of deep ecology. In this point, this generation can be said to solely look for the "environmental ecology". On the other hand, although being a shallow style as TREND, the 2<sup>nd</sup> generation widely intended the "social ecology", in the respect that it has been aiming at sharing the environmental problem with the society as a whole. In this context, such task will be referred to the 3<sup>rd</sup> generation as how

to be able to introduce the "mental ecology" into the environmental arguments. After passing through two contrastive generations, the 3<sup>rd</sup> aims at the new way of subjective behavior. It is NORMAL.

#### IV -Conclusion

NORMAL is an integration, a sublation or a moderation of the former two generations, because the environmental consciousness remains for our whole society as the 2<sup>nd</sup>, and tries to be much deeper than just one item of TREND, looking for a real social change.

In considering the subjectivity of this generation, I would like to take up here the thought of the "*Mingei*", the Japanese Folk Crafts movement since the beginning of 20<sup>th</sup> century, which has been prevailing again among Japanese people, especially young generation of designers or artists since around 2000. What *Mingei* aims at is "the mediocre, the ordinary, the plural, the public and the common world nobody monopolizes" (YANAGI 1941). It's easy to grasp a resonance between *Mingei* and the 3<sup>rd</sup> generation mentioned here. But the point is that there is, behind this resonance, some desire for a sensitivity of the importance of our normal daily life. I would like to name such sensitivity "intimateness" with one's own life and society and to consider that creating and sharing this intimateness is the happiness for our generation.

#### V - References

Félix GUATTARI, "*Les trois écologies*", Paris, 1989.

Muneyoshi YANAGI, "*Mingei towa nanika (What is Mingei?)*", Tokyo, 1941.

## 《Happiness》 Glossary

**Altruism** : 【利他主義】 is the principle or practice of concern for the welfare of others.

**Capabilities approach** : a theory, mainly held by Amartya Sen and Martha Nussbaum, that any social and political conception of justice must stem from reflection on the quality of life. Sen and Nussbaum denounce welfarism (in sense 2/), pointing out that painful conditions of life can lead to an adaptation of individual desires and preferences such that declarations of self-satisfaction can be in disaccordance with the actual quality of life. According to them, the economics of development need to define some fundamental conditions of the human good life, that is, define the conditions in which human capabilities can be developed.

**Consequentialism** : a theory holding that any action is evaluated according to the results, and not to the nature, of the act or to the intention behind the act. One kind of consequentialism holds that the value of an action depends on the satisfaction procured by its results.

**Deep ecology** : 【ディープ・エコロジー】 is a contemporary ecological and environmental philosophy characterized by its advocacy of the inherent worth of living beings regardless of their instrumental utility to human needs. It aims at radical restructure of modern human societies, based on the idea of fundamental criticism on humanism.

**Deontologism** : a theory holding that the value of any action is that it performs or intends to perform what it has to perform according to any rational law or moral duty (worthing independently to any sensible pleasure or particular interest). In the history of philosophy, Immanuel Kant is the major figure in this approach.

**Ecosophie** : 【エコソフィ・環境知】("ecosophy" in English) is neologism focusing on the new type of knowledge, formed by contracting the phrase ecological philosophy. The most famous examples are that of the Norwegian father of deep ecology, Arne Næss (1912-2009), and that of French postmodern philosopher and psychoanalyst, Félix Guattari (1930-1992).

**Egoism** : 【利己主義】 is placing concern with oneself or one's own interests above the well-being or interests of others.

**Hedonism** : theory holding that the value of action is pleasure, or some kind of pleasure which is more constant, or less complicated by pain. In the history of philosophy, Epicurus is the major figure in this ethics.

**Mingei** : 【民藝】 (*Min* "folk" + *gei* "craft" in Japanese) is the Japanese folk crafts movement, which was developed by Japanese philosopher, Muneyoshi Yanagi (1889-1961) and his swarm friends in the beginning of 20th century in Japan. The philosophical pillar of *Mingei* is reevaluation of hand-crafted art for ordinary people and complete reform of daily lifestyle in modern societies.

**Moderation** : 【中庸】 is a principle of life, eliminating or lessing extremes and ensuring normality.

**Normal** : 【ふつう】 is the one of key concepts for modern product design. Japanese product designer, Naoto Fukazawa, who was installed in the position of director of *Nihon Mingei-kan* (the Japan Folk Crafts Museum) in 2012, selected the typical items for modern daily life with English product and furniture designer, Jasper Morrison, and exhibited them under the name "Super-Normal" in 2006.

**Subjectivity** : 【主体性】 is a term used to refer to the condition of being a subject : i.e., the quality of a subject's perspective, experiences, feelings, beliefs, and desires. Subjectivity is used as an explanation for what influences and informs people's judgments about truth or reality.

**Sublation** : 【止揚】 is a translation of German term "Aufheben" or "Aufhebung", which has several seemingly contradictory meanings, including "to lift up", "to abolish", or "to sublimate". Especially in philosophy, *aufheben* is used by Hegel to explain what happens when a thesis and antithesis interact.