Recommendations from the 2nd Cluster for Pioneering Research Advisory Committee (AC) to President Makoto Gonokami

31 August 2023

Prof. Dr. Hans-Joachim Freund, Chair

Prof. Dr. Klaus Blaum, Co-Chair

Prof. Dr. Iain Mattaj, Co-Chair

Prof. Dr. Laura H. Greene

Prof. Dr. Mutsuko Hatano

Prof. Dr. Rebecca Heald

Prof. Dr. Takashi Nakano

Prof. Dr. Hiroyuki Noji

Prof. Dr. Rasmita Raval

Prof. Dr. Heike Riel

Prof. Dr. Michael Roukes

Prof. Dr. Yumiko Saga

Prof. Dr. Hans-Peter Steinrück

Prof. Dr. Hirokazu Tamura

Prof. Dr. Zhenfeng Xi

Prof. Dr. Fu-Chun Zhang

EXECUTIVE SUMMARY

From Aug. 28th, 2023 to Aug. 30th, 2023, this Advisory Committee (AC) was provided with an overview of RIKEN's "Cluster for Pioneering Research (CPR)". A series of oral presentations in combination with a poster session and site visits and a comprehensive set of written reports were presented to us and clearly showed the individual excellence of the research carried out within the CPR. RIKEN and CPR are known as platforms, where excellent, pioneering researchers in different fields, covering Physics, Chemistry, Biology and Engineering, are put in a position to carry out world-leading scientific work that cannot be performed elsewhere in Japan. This requires providing the PIs with the freedom to pursue a bottom-up approach, which is the mission of CPR, in combination with independence and a notable budget. The latter seems not to be provided adequately, at present, which, in our opinion, puts the outstanding excellence of RIKEN at risk.

TERMS OF REFERENCE

TOR 1: Evaluate the responses to the 2019 AC recommendations

The Advisory Committee appreciates the responses to the 2019 AC recommendations provided in chapter 4.2 of the present report. We noticed that CPR took the recommendations very seriously and the actions taken are well-thought through. To highlight three specific responses: 1) The contribution to society became especially apparent during the Corona pandemic where Watanabe's lab made significant anti-COVID research achievements. Also, the outstanding work on ultra-thin organic solar cells made significant contributions to sustainability, one of the most pressing problems of society. 2) The committee is impressed by the fast implementation of the RIKEN Core Facility Management System "R-COMS" for shared-use equipment. This will provide access to singular equipment to all PIs and Hakubi TLs of RIKEN. Close to 700 registered instruments up-to-date and more than 200 laboratories using them is a clear sign for the success of this initiative. 3) CPR put a lot of effort into improving the interaction between junior scientists on the PhD and postdoctoral researcher level. Especially workshops and retreats were held as networking events which should be continued and enhanced in order to overcome isolation of younger researchers.

Obviously, the CPR's budgets are defined by RIKEN headquarter and we took note that negotiations are ongoing. However, we still feel that the financial situation of some of the CPR's PI budgets is such that international competitive work cannot be carried out any longer. We strongly advise to evaluate the financial situation critically and to compare it to international competitive research institutions.

The advisory committee noticed that not all recommendations given by the AC in 2019 have been listed and commented on in section 4.2 of the present report. E.g., it was

recommended “broadening the pool of applicants by advertising and aggressively recruitment efforts” in order to increase the representation of women and international participants within CPR at RIKEN. Whether this has happened or not cannot be judged by the advisory committee since no information has been provided, but the committee noticed that the situation concerning the diversity of scientists, post-docs, and graduate students has not changed much since the last AC meeting. Once more, in order to attract the best candidates for the highly prestigious PIs position at RIKEN, international advertisement and a broad search is mandatory. For the benefit of future ACs we ask that the response to every recommendation, rather than to only a selection, be provided in the CPR Director’s overview.

TOR2: Based on the results of the Center’s self-analysis, evaluate operations and R&D activities for the 4th Mid-to-Long-Term Plan period (FY2018-2024).

The AC evaluated the four major research areas of CPR, Physics, Chemistry, Biology, and Engineering. We also met the non-PI scientists for discussion. Our impressions are detailed below.

Physics

RIKEN conducts cutting-edge research across wide areas of physics with state-of-the-art research facilities, including particle accelerators and experimental setups, and includes broad international collaborations. A strength of RIKEN is that specific research projects and focus areas can, and have, evolved over time.

There are presently 15 Chief Scientists (CSs) in Physics at RIKEN, that include 5 recent retirees and 6 new hires. This turnover is providing opportunities for diversifying the CS population in research area, gender, and serves to bring in young people.

We heard two research presentations. The first was by Takehiko Saito who presented innovative research in nuclear physics, invoking state-of the art detection techniques that he is using at facilities in Japan, Germany; and in the future, China. In particular, his group is using machine learning to analyze these large data sets, thereby extracting, among others, exceptionally precise values of hypernuclear binding energies. This work is one of the research activities securing RIKEN’s international standing in nuclear physics, which also include leading research at RI Beam Factory in RIKEN as well as at J-PARC and other facilities.

The second presentation was by Erika Kawakami, a RIKEN Hakubi TL, using state-of-the-art cryogenics, materials, and measurement techniques, exploring extremely novel directions to develop qubits for quantum information sciences. It was gratifying to see RIKEN supporting CPR to carry out this high-risk, high-reward research direction.

The astrophysics research is world-class, showing leadership and innovation. For example, within research on planet formation, ALMA observatory data have been combined with data measured in their laboratories, JWST spectroscopic data, and mass spectroscopic data obtained from comets. Similar convergence research was applied to how black holes affect galaxy formation.

Condensed matter physics, covering experiment, theory, and computation has seen some retirements of the CSs in the past few years. This field of physics encompasses several fundamental research areas, including basic understanding and discovery of new unconventional superconductors, thermoelectrics, and topological materials. It also includes research into new materials candidates for qubits for future quantum sensing and quantum information sciences. RIKEN itself does already have strong, established research centers in condensed matter and materials research, but new and innovative CPR CSs in these areas that are very quickly growing on an international scale are needed to keep RIKEN innovative and at the forefront of research in quantum materials.

Condensed matter and materials research is, by nature, convergence research, and any new CSs would gain by RIKEN supporting collaborations across chemistry, biology, and engineering, because, for example, we do not know what the “next qubit” will be, and such discoveries will require collaboration across these fundamental areas of materials research.

Chemistry

The research performed by the CSs in the field of Chemistry is very high standard and competitive, yielding world class results. The AC was very impressed by the very high quality of scientific projects, and the excellent to outstanding performance of the CSs in Chemistry, who cover the fields of Organic Chemistry, Chemical Biology, Computational Chemistry, Physical Chemistry, Astrochemistry, Surface Chemistry, Inorganic Chemistry, Polymer Chemistry and Catalysis. This broad expertise is a big asset of the Cluster of Pioneering Research, which enables high-level collaborative research activities, and which should be kept in the future. The individual projects all address very interesting and timely topics making use of the excellent research environment at RIKEN. The CSs are very productive, with many publications in outstanding journals. Moreover, the CSs have received numerous awards and

distinctions (in total >25) since 2019. Three CSs have co-affiliations with Universities (U-Tokyo, TokyoTec, Nat.Inst.Nat.Science), which is considered essential for joint funding applications and for young researchers in order to obtain experience in teaching. Moreover, collaborations exist with many other national and international universities worldwide. Recently, two CSs retired (Yukishige ITO and Reizo KATO), one more will retire later in 2023 (Mikiko SODEOKA) and one moved out to U-Tokyo. Simultaneously, two excellent scientists, Takuya HASHIMOTO and Genki KOBAYASHI, have been appointed as new CSs in 2022, and a high-potential young scientist, Yuya MORIMOTO, was installed as Hakubi Team Leader. Moreover, the Chemistry field was quite successful in receiving pioneering projects in the last years (Evolution of matter in the Universe / Nami Sakai (CPR), Single Molecule Science / Tahei Tahara (CPR/RAP)).

In the oral presentation, two examples of the outstanding research in the field of Chemistry were presented: CS Nami Sakai (Star and Planet Formation Laboratory) impressively addressed the Evolution of Matter in the Universe. There is an interdisciplinary and critical mass of researchers contributing to this pioneering research theme, which maps both chemical evolution (major elements and molecular diversity) and star and planet formation. This broad and holistic approach is highly ambitious, and is enabled by high-resolution observations using multiple instrumentation, achieving length scales down to 10 au, and collecting sufficient data to enable semi-statistical analysis ranging from molecular clouds to protostellar and protoplanetary systems. Clear indications of international leadership, competitiveness with high impact publications, and the broad base of in-house RIKEN expertise in space observations, gas and surface phase reactions, modeling and analysis should enable continued dynamism and competitiveness of this theme. CS Katsunori Tanaka (Biofunctional Synthetic Chemistry Lab) has made great achievements on therapeutic in vivo synthetic chemistry, an area which on the one hand is highly fundamental and of practical significance, but on the other hand is very challenging, because synthetic reactions in flasks are very different from synthetic reactions in-body. The group has developed several in vivo metal-catalyzed reactions, carried out chemical transformation of cancer metabolites, and already realized the 1st clinical trials in the world, through active collaboration with several hospitals.

There is presently only one Hakubi team leader in Chemistry. We recommend increasing this number. Internal communication within the Chemistry field, in particular between the more senior and the new members, should increase.

Biology

The field of Biology in CPR has historically been first-rate, and in particular, the Hakubi team leaders are doing very well and have indicated that CPR is providing them with an excellent experience. These team leaders could be a great resource for the future.

With upcoming retirements, only four current chief scientists will remain on the Wako campus in 2027. This is both a threat and an opportunity, and CPR needs a strategy to recruit new chief scientists. The interdisciplinary nature of the CPR is a great strength and the recruitment of Shino Suzuki to start the geobiology and astrobiology laboratory is an excellent example of how CPR can leverage this strength. We recommend that CPR biology PIs at all career stages work together to define what is pioneering and recruit new chief scientists that explore new, interdisciplinary areas of research.

In the field of biology, many of the strengths, such as R-COMS, and challenges, including the need for an independent CPR director and an increased and more flexible budget, are common with the other CPR areas. One specific issue is the existence of several RIKEN centers in the field of biology, including the Center for Biosystems Dynamic Research, the Center for Brain Research, and Center for Integrative Medical Science. These centers currently compete with the CPR for new chief scientists. Furthermore, CPR chief scientists frequently rely on external funding that supports small or medium scale projects rather than ambitious, pioneering research. These points again highlight the need for CPR to define their identity and aspirations to distinguish themselves from existing biology centers and recruit and support scientists who are highly motivated to explore new research fields.

Engineering

Some exceptional activities are being pursued by CPR CSs within the engineering sector. It was a great pleasure for the Advisory Committee to learn about this work. RIKEN's engineering resources and infrastructure are generally very good, and many scientists expressed satisfaction with being part of the CPR cohort, given its cross-disciplinary nature and its focus on pioneering basic science.

Below, we highlight just three areas of CPR engineering research:

Katori has made outstanding contributions to the invention and development of optical lattice clocks, which garnered him the 2022 Breakthrough Prize in Fundamental Physics. His efforts have enabled world-leading precision tests of the fundamental laws of nature with a new type of ultra-precise optical lattice clock. He and his group have tested the gravitational redshift in a very special test environment, the Tokyo Skytree, and have obtained results with an uncertainty of 1 part in 105. Surprisingly, given the extreme difference in costs, this is competitive to that of space-borne experiments.

Kato is carrying out conspicuous and exciting research at world-class level on single-quantum photonics and novel quantum photonic devices. He has established impressive and excellent infrastructure within his RIKEN group, and has developed novel approaches for carrying out challenging experiments with novel materials. These include two- dimensional structures, nanotubes, and hybrids between these two types

of structures. He has also established high-profile international collaborations, notably on nanotube functionalization, that are expanding and further strengthening his group's unique research capabilities.

Ishibashi has been pursuing excellent and ambitious basic research to study the fundamental physics of nanoscale structures and to conceive of and demonstrate novel quantum information devices. He and his team are at the forefront of the field of

topological insulators. These are hybrid superconductor-semiconductor structures in which control over the quantum states of electrons and spins enables novel quantum phenomena, materials, and devices. This is indeed an active and important area of research worldwide; and we suggest RIKEN may want to consider this field among others for recruitment of new CSs.

There is a perception within the Engineering cohort that engineering is not entirely appreciated within the larger framework of RIKEN and CPR. Perhaps this is because Engineering is considered applied and not pioneering research. We strongly suggest that the concept of Pioneering Research within CPR be expanded to not just encompass fundamental research but also groundbreaking paradigms in applied research. Among such efforts could be new methodologies for realizing and producing advanced technology, the creation of intellectual property (patents), implementing new and efficient approaches to technology transfer, and support for innovative testbeds for industrial collaboration that streamline interactions and eliminate red tape.

Within the CPR Engineering cohort there is also the perception that efforts toward commercialization are largely unsupported and unappreciated. Such efforts include the creation of intellectual property (e.g., via patent applications), the formation of start-ups, technology transfer to enable commercialization of RIKEN engineering achievements.

Opinion exchange with non-PI scientists

The non-PIs within CPR were left out of the Review. Some of them knew it was scheduled but only a week before were told they could not attend. We recommend in future that all CPR scientists be invited to the presentation to the AC.

After separate meetings with the CPR non-PI cohort, the AC came to the consensus that this group feels isolated from the rest of RIKEN. Among apparent issues are: Recruitment: The non-PIs should be aware of the hiring process and attend the presentations of CS applicants.

Lack of cross-CPR interaction: More frequent Colloquia would be helpful to learn about the other CPR groups at RIKEN and help promote convergent, cross-disciplinary research.

Communication: RIKEN and the PIs don't seem to know how non-PIs find jobs after their RIKEN employment. If a postdoc is too long (e.g. >4 years) it is detrimental to their career. Although this can help the PI, it may harm the future employment prospects for the non- PI. The AC feels that mentorship to provide more career development information, including future employment possibilities, to the non-PIs is essential. A possibility could be to engage senior or retired PIs to stay on as mentors to non-PIs. Their wealth of experience could be extremely valuable.

TOR3: Evaluate the policies of the 5th Mid- to Long-Term Plan period (FY2025-2031) and recommend new directions for operations and R&D that should be implemented and promoted.

On the first day of the meeting, the CPR Director outlined the vision of the CPR for the next mid- to long-term planning period. The Director and, on the second day of the meeting also the CSA chair, described the three missions that make up this vision; Promoting the leading-edge research production by Chief Scientist laboratories including some expansion of this area, exploring new fields of research via Pioneering Research Projects and effectively managing shared-use facilities. The review panel supports these goals and is also persuaded that the mechanisms proposed to achieve success in these missions, including 1. more direct involvement of the CPR CSs in choosing new research field in which to open searches, 2. the reorganisation of the CPR to become a Pioneering Research Institute led by the institute Director and 3. the possibility to directly promote the best ECL PIs into chief scientist positions by a simplified process, are all sensible changes that will help this area of RIKEN to achieve even more success in future. We go into more detail on some of these points below.

The Transformative Research Innovation Platforms (TRIP) initiative makes the excellent proposal to incorporate quantum-classical computing and Artificial Intelligence methods to the areas in which CPR is active. The AC unanimously supports this idea. It is however very important not to overstate the potential of this initiative in the short term. Enabling a shift from "prediction of the future to controlling the future" is not realistic in the foreseeable future. The AC recommends to follow the TRIP plan while being realistic about what will be deliverable in the next decade.

The AC is of the opinion that the Director of CPR should be empowered, in concert with the CSA, to enhance several aspects of CPR. Specifically, the CPR should be allowed to make proposals about new research fields for recruitment in a manner identical to RIKEN's other Center Directors. In other words, CPR should be able to define areas of interest, and suggest that calls be opened to select (by the standard RIKEN process) Scientists to fill these positions.

The CPR Director should also be able to negotiate with RIKEN management to establish CPR's budget in the manner of RIKEN's other research centers. Further, it is important that in CPR's management processes transparency is significantly increased and complexity reduced. We heard many complaints about the lack of transparency in CPR's decision-making processes and its unnecessarily complex administrative processes.

There is perception amongst CPR CSs that other RIKEN centers are a threat to CPR (in terms of budget, recruitment, etc.). It was pointed out that CPR has less funding compared to strategic/infrastructure research Centers in RIKEN. CPR's core mission is to generate seeds for future research programs; accordingly, we recommend that RIKEN allocate CPR a reasonable fraction of the entire RIKEN budget.

We learned about the new Early Career Leader (ECL) PI program, which is an excellent follow-up to the Hakubi program. A suggestion was made that these PIs, at the end of their ECL period, should be able to apply for a CS position. Provided that such potential promotions are evaluated as stringently as in other CS hiring processes, the AC supports this proposal.

In terms of fostering (mentoring) young PIs, we learned that each young PI chooses two CS mentors. We suggest that this group of three should meet at least four times in the first year and twice each year after that. The mentors should also be available for informal consultation between these meetings. A "Mentor of the year" award would help ensure that this program is supported by the CSs.

It was also pointed out that commercialisation efforts are part of what might be called the original "RIKEN DNA." Specifically, several of the chief scientists in RIKEN's early years were also very successful entrepreneurs. Within CPR, there is groundswell of enthusiasm for a renewal of commitment to these original paradigms – which the AC also supports.

RIKEN has a long-standing problem of diversity and a mechanism to overcome this is overdue. Currently only one in five RIKEN executive directors is female and there are no female Centre Directors. This is very unhelpful in an organization attempting to increase diversity and must be changed. In addition, a system of making open calls with no specific topic and encouraging, by direct contact, female and foreign applicants would be useful to increase recruitment of PIs from these categories. Many institutions also carry out calls with the understanding that no recruitment will be made unless an outstanding female or foreign researcher applies and can be selected. We suggest RIKEN examines the methods that have been successful in increasing diversity elsewhere. We recommend that RIKEN should also work to construct a pipeline that includes special attention to recruitment, mentoring, and leadership training for female and foreign scientists.

We were told the CSA chair and vice-chairs have too many duties. Although we have insufficient information to suggest in detail how to correct this problem, we encourage the current chair and vice-chair to delegate some of their tasks. We suggest that this proposal be discussed within the CPR and a suitable solution be found.

The RIKEN President announced his intention to improve interaction between RIKEN and Universities. The AC supports this proposal and recommends that all RIKEN PIs

should have the possibility to have a joint appointment with a University if they wish to do so.

The AC was surprised to learn that the singular opportunities for young scientists within RIKEN are not widely known in Japan. As programs such as the ECL initiative offer the prospect of early independence for young Japanese scientists, we encourage RIKEN to widely communicate these opportunities, both across Japan and internationally. This should greatly enhance its recruitment efforts, especially at this time when multiple CS retirements and departures are impending.

The AC was informed that the Wako campus has increasingly severe space constraints. Indeed, we observed several cases of space limitation during our visits to the laboratories. We recommend that the CPR Director discuss with RIKEN leadership how to relieve this problem.

POSTSCRIPT

We offer these, hopefully constructive, comments in the spirit of helping RIKEN, and the CPR in particular, to achieve an even higher level of achievement. **Our overarching assessment is that we are deeply impressed by the achievements of the CPR and of the scientists involved.**