Reference 1

National R&D Agency

Institute of Physical and Chemical Research

Mid to Long-Term Plan

(Draft)

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National R&D Agency, Institute of Physical and Chemical Research

Table of Contents

(Preface)

The document describes the Plan for Achieving Mid to Long-term Objectives (“Mid to Long-term Plan”) of National R&D Agency, Institute of Physical and Chemical Research for a period of seven years from April 1, 2018 to March 31, 2025 pursuant to the provisions of 5-1, Article 35 of the Act on General Rules for Incorporated Administrative Agency, and Article 5 of the Act on Special Measures Concerning the Promotion of Research and Development by the Designated National Research and Development Agencies (“the Act on Special Measures”).

I. Measures for achieving the objectives of maximizing R&D outcomes and improving the quality of business

1 Establishment and operation of the research institute management system to maximize R&D outcomes and create innovation

The Institute of Physical and Chemical Research (“RIKEN”) is expected to be the core institute to vigorously drive innovation in Japan as a designated national R&D agency and the world’s best general scientific institute. For this purpose, RIEKN will produce the world’s best R&D outcomes with its excellent scientific capability, as well as intending to be the model for other national R&D agencies by continuously presenting outcomes from vigorous basic research.

In addition, striving to be the world’s preeminent research institute, RIKEN Initiative for Scientific Excellence aims to: 1) Pioneer a research management model for maximizing research and development results, 2) Lead the world in achieving new research and development results through scientific excellence3) Become a hub for science and technology innovation, 4) Serve as a focal point for global brain circulation, and 5) Foster the development of world-class leaders in scientific research as the pillars of this mid to long-term plan.

According to the Initiative for Scientific Excellence, RIKEN will create new sciences, and strive to lead society for creating innovation through co-creation on RIKEN’s initiative.

(1) Reinforcing the system and function to support management under the president’s leadership

RIKEN is required to produce the world’s best R&D outcomes which are the basis for science, technology and innovation as a designated national R&D agency, and act as the core agency to vigorously drive innovation systems in Japan. For this purpose, RIKEN will always pioneer new research fields as the world premier R&D agency, and under the leadership of the president, reinforce the research management function for creating innovation and provide an excellent

research environment and advanced research systems serving as the model for other national R&D agencies.

○ Reinforcing the system and function to support management judgment

As a core leader of R&D for creating innovation in Japan, RIKEN will conduct R&D systematically with the clear sense of mission for accomplishing political issues according to science, technology and innovation policies including the Science and Technology Basic Plan, and promote R&D in response to various demands from society in a strategic and focused manner. When innovative insights on science and technology are found, or internal or external situations of science and technology significantly change, and R&D or other operations are required for addressing the insights, RIKEN will immediately take actions in sufficient communication with the Minister of Education, Culture, Sports, Science and Technology.

Appropriate advice from the RIKEN Committee for Research Strategy (tentative) composed of experts in and out of RIKEN for investigating management of the agency and research themes to promote, and RIKEN Science Council where core scientists discuss the direction of R&D to be promoted by RIKEN from scientific perspectives will be reflected in the management of the agency.

○ Administration based on management judgment

The implementation state of all research projects is completely identified for maintaining suitable administration across the agency, and budgets and personnel will be allocated according to management judgment based on management policies of the president including necessity and urgency, and in-depth discussions.

Necessary funds will be allocated to the research to be started early to meet national strategy or social needs, or research expected to produce outcomes by being accelerated early, in a flexible manner by management judgment from the expenses at the discretion of the president.

Strategic research expansion operation will be promoted for setting strategically or politically critical themes and creating R&D outcomes, and at the same time, an original research proposal system will be implemented to select and conduct challenging and original research subjects which are potentially producing new fields of research in future, and develop them to new businesses.

○ Proper evaluation of R&D management and feedback

Management of the agency and implementation of research subjects will be evaluated on an international level by external, internationally respected experts. The RIKEN Advisory Council (RAC) will be held at regular intervals, and the Advisory Council (AC) at each research center for evaluating management of the entire agency.

Results of evaluation by the RAC, etc. will be fed back to the allocation of budgets, personnel and other resources including the review of the improvement or elimination of laboratories, and as a suitable response to the evaluation of an incorporated administrative agency, proactively used in the investigation into the method of strengthening R&D activities. Evaluation results are made public on the web site, etc. in principle.

Research activities of RIKEN will be optimized by flexibly reorganizing research projects, with some terminated early, some expanded or promoted in overriding priority based on management judgment according to changes in social or political need, or long-term research strategy of RIKEN.

○ Innovation design and formation of engineering networks

Visions of future society and scenarios for realizing these visions will be drawn by analyzing the relations of science and technology with society in detail. RIKEN will develop innovation designers who proceed with this task through dialogues with mainstream researchers. New value standards will be placed in the scenarios written by innovation designers based on the proposal of critical issues in research and realization of visions by implementing the proposal. Innovation designers will provide the place for co-creation for various stakeholders in industry-government-academia collaboration through the processes of co-creation.

In addition, it is increasingly difficult to solve complicated and shifting social issues such as aging society with a declining birthrate or climate change by simply conducting segmented sciences. Accordingly, an engineering research approach will be taken so that world-leading scientists and engineers in individual research fields can build horizontal networks beyond their relevant fields and interact with innovation designers to solve problems.

(2) Improving the research environment and developing outstanding researchers to produce the world's best research outcomes

○ Development of young researchers

Efforts to develop human resources ranging from students to young researchers, and their qualification such as independency and autonomy will be improved using various systems such as Junior Research Associate, International Program Associate and the Special Postdoctoral Researcher (SPDR) in close collaboration with universities in Japan and abroad. Next-generation researchers will be nurtured in a system in which they are assigned as the leader of a laboratory if the chosen research field is an unexplored or ambitious field (RIKEN Hakubi Fellows Program).

○ New personnel and employment systems

Permanent positions are provided to attract outstanding researchers and allow them to engage in their work in more stable conditions without worrying about term set contracts. Around 40 percent of researchers will be assigned to the permanent positions after fair and strict evaluation with the fields to be promoted on a mid to long-term basis in mind. A stable research environment will also be assured for fixed term researchers by prolonging their term to seven (up to ten) years in principle for making the most of human resources in research centers in a flexible and efficient manner and fostering researchers who play active roles in universities and research institutes in Japan and abroad.

In addition, permanent employment is also applied to administration staff, such as coordinators (research administrators) responsible for providing advanced research assistance across the agency in an attempt to secure human resources.

○ Reinforcement of a system to support R&D activities

Administration work for promoting research at the research center and management work will be effectively allocated in every office to reinforce research assistance function for supporting R&D activities. In addition, a multi-layered research promotion and support system will be provided at every research center or organization to improve research environment so that researchers can concentrate on their work with the support of coordinators for outreach activities, research fund acquisition, academic conventions, and joint research with universities and external organizations, and research assistants having research career and acting as advanced support specialists. The work may be improved in time by reviewing and eliminating unnecessary work.

○ Promotion of diversity

Efforts will be made for establishing a research environment to secure more diversified human resources.

The research environment will be maintained so that female researchers can continue their R&D activities during, and before or after child-rearing and nursing care by balancing between work and family based on the gender equality concept.

Foreign language ability at administration division will be further increased to maintain international environments including various supports for foreign researchers. Various efforts so far will be reviewed and improved to increase convenience.

Supports for employment of persons with disabilities will also be accelerated across the agency.

Through these efforts, diversity will be assured, for example, by maintaining the proportion of female researchers in the leading position (10% in the objectives of the 3rd Mid to Long-term Plan) and foreign researchers (around 20% in the objectives of the 3rd Mid to Long-term Plan).

<Under discussion>

○ Internationalization strategies

Efforts to build mutually-beneficial international collaboration will be promoted according to internationalization strategies for creating the world's best research outcomes through international cooperation and establishing a positive international brain circulation as a hub of international science and technology. Specifically, international cooperation research centers will be opened in Asia, the U.S. and Europe for exchanging memorandum of understanding with overseas research institutes and universities, concluding research cooperation agreements, conducting international joint research, and boosting international exchanges by dispatching or accepting human resources. The state of endeavor will be closely investigated in time for promptly making an end of completed joint research and unnecessary center.

○ Information disclosure for improving awareness of R&D activities

Information on outstanding R&D outcomes and expected social return will be disclosed to the public in a positive manner to improve public awareness by press conferences, PR brochures, web sites, SNSs, facility tour, scientific lectures held in various locations and meetings with media.

In press conferences and PR brochures, information will be provided for the public in an easily understandable way using plain words and images. RIKEN strives for obtaining broader understanding and support from various layers of people in Japan and abroad through seminars and visited lectures in addition to facility tour and various lectures.

Information will be distributed overseas through press conferences with foreign media and RIKEN Research to improve international alliance and secure international human resources.

(3) Promoting social return of research outcomes through close collaboration with related organizations

The world's most advanced and innovative research seeds, produced by RIKEN, will be transferred to social values effectively and promptly to create science, technology and innovation, and improve co-creation with industries, universities, national R&D agencies, and local governments, etc. Specifically, sharing of knowledge about future trends in and out of Japan, social needs, business needs and technologies to solve these issues will be promoted in close collaboration with industries, universities, national R&D agencies, and local governments, etc., and an alliance with innovation design activities will be established.

○ Improving co-creation with industries

Open innovation will be promoted for searching needs, creating new technological development themes and its commercialization to maximize research outcomes and solve social issues, considering in part trends of other nations. And, co-creation with industries will be reinforced on the one-to-one collaboration basis between organizations. Accordingly, strategic co-creation themes will be created by organizing collaboration teams consisting of interdisciplinary and inter-industry members for opening collaboration centers consisting of multiple research teams from industries and RIKEN, collaboration programs that integrate all processes from planning of research to creating outcomes through cooperation between industries and RIKEN, and integrative collaboration in research for finding solutions under the auspices of industries to finally assemble these efforts to a large-scale, collaborative research. In doing so, coordinated project management is essential for the steady progress of project and social implementation of outcomes.

To provide strong support for starting RIKEN ventures based on research outcomes, judgment of technological superiority and market research will be promoted as part of an integrated support including business planning, management and financing with cooperation

from external venture capital etc.

R&D for boosting up research outcomes at the basic research stage to those at the demonstration stage, and R&D for improving intellectual property right will be conducted to obtain high quality intellectual properties that can be used in industries. In addition, licensing activities for intellectual property right will be highly promoted by packaging or value chaining multiple patented technologies.

○ Establishing and improving science and technology hub capability

RIKEN will increase the scientific excellence of Japan and create innovation by working with universities, research institutes and industries, act as a hub for science and technology, and build and improve R&D networks. On this account, it has to create innovative research outcomes and seeds for basic research by not only limiting to alliance resulting from conventional individual joint research by researchers but also constructing a system enabling joint efforts in one-to-one collaboration between RIKEN and individual universities highly capable of R&D and industry-academia collaboration, and realizing cross-sectoral, integrative research with organizations each having indigenous advantages. It will also attain brain circulation by building networks with external organizations like universities using the cross-appointment system, etc., and foster young researchers and students. RIKEN will hold collaborative forums and symposiums with industries, local governments and related organizations etc. to introduce the obtained research outcomes, while promoting the introduction of the outcomes created in new joint research projects in industry-government-academia collaboration into society with a view of vitalizing local industries.

○ Research supporting collaboration with industries

Drug discovery and medical technology platform program and preventive medicine and diagnosis innovation program will be launched for promoting collaboration to realize a society of health and longevity, and build a health and medical data platform.

In drug discovery and medical technology platform program, candidates for pharmaceuticals including novel materials such as low-molecular compounds, antibodies and nucleic acids, and candidates for cellular pharmaceuticals will be created from drug discovery targets (disease-related proteins), identified in various basic disease studies at research centers and universities, to obtain valuable intellectual properties, and delivered to private enterprises

or medical institutions at appropriate nonclinical or clinical stages during translational research. Accordingly, a management office will be provided for this program to allocate suitable professional staff, and integrate drug discovery platform units at each center for effective and efficient prioritization and progress management of resources. Collaboration with universities and medical institutions will be reinforced by ministry and office supports for academic drug discovery research, and making plans and coordination for expanding advanced technologies to drug discovery research.

In a preventive medicine and diagnosis innovation program, efforts such as joint research for making preventive medicine and diagnostic technologies available at clinical sites by matching achievements of various basic studies and research basis at RIKEN research centers with the needs of medical institutions and private enterprises.

In addition, a health and medical data platform will be established by combining data gathered from RIKEN and collaborative medical institutions, multi-omics data newly obtained and drug discovery related data owned by drug companies in collaboration with RIKEN Center for Advanced Intelligence Project to achieve advanced individualization medical care. Efficiency of the inference model (disease predictive inference model) for predicting the disease morphologies of individual patients and changes in future will be improved using machine learning and mathematical and theoretical science approaches, and a hybrid drug discovery process proposal system for creating new drugs and medicines will be developed using machine learning and simulations. Optimization methodologies will also be developed to enhance algorithms and proposals for drug discovery processes based on the disease predictive inference model for achieving more advanced medical care and drug discovery.

(4) Exploiting and creating new science to support sustainable innovation in Japan

A Pioneering Research Headquarters (tentative), aiming at exploiting and creating unexplored and unknown scientific research fields, will be launched based on the long-term strategies of RIKEN to accelerate the great progress of science and technology, and support the creation of sustainable innovation. Researchers representing various fields of science will engage in their own work as well as cross-sectoral research at the Pioneering Research Headquarters.

○ Promoting basic research for creating new science

At the Pioneering Research Headquarters, the researchers in various fields having outstanding achievements and excellent leadership will head the laboratories. Researchers

may produce surpassing basic research outcomes by conducting research in cooperation with researchers and research organizations in and out of the agency, while inspiring each other, and strive to create new sciences by identifying new research fields and subjects, without the need for adhering to pressing issues or short-term missions, and in defiance of constraints in differences in research fields and organizational walls. In this process, long-term perspectives focusing on science in society and practical use of basic research outcomes will be taken into consideration.

○ Promoting cross-sectoral projects

Integrative and cross-sectoral R&D subjects that can be candidates for strategic R&D for meeting national and social demands will be conducted based on the management strategies of RIKEN by getting outstanding researchers inside and outside RIKEN together. Research will be evaluated in time by R&D subject, strictly reviewed according in part to international R&D trends for finding new research fields.

○ Building function of common base network function

More efficient use of research resources will be promoted by visualizing the presence and utilization methods of common base research facilities and equipment in RIKEN. A system that can be used in the agency without intervening primary tasks of RIKEN will be developed in the light of facilities and equipment in RIKEN that can be used as the common research base, developed in promoting strategic R&D for meeting national and social demands.

2 Promotion of strategic R&D based on national and social demands

RIKEN will promote R&D of national issues listed in the Science and Technology Basic Plan, in a strategic and focused manner, as a core research institute in the science, technology and innovation policies in Japan, and accomplish R&D projects listed below in collaboration with universities and research institutes in and out of Japan:

Research details are covered in appendixes.

(1) Advanced intelligence projects

Under the global research system for realizing a “super smart society” by using ICT: 1) generic technology research will promote R&D for establishing innovative core technologies such as AI, and 2) goal-oriented technology research will strengthen science and technology

fields Japan has advantages and solve social issues by using these core technologies.

At the same time, it is also important to increase insights on the effect of technological progress on society and relationships between AI and humans. Accordingly, 3) ethical, legal and social issues of AI application will be studied as research of AI in society and information disclosed.

Considering that it is imperative to understand knowledge and technologies concerning ICT, and develop human resources that are capable of solving issues, 4) a flexible research systems and environments suitable for recruiting human resources with a variety of skills from a wide range of fields as appropriate will be established under the good leadership.

(2) Theoretical and mathematical sciences

Sciences in various fields will be promoted in an integrated manner to achieve interdisciplinary research based on mathematical and theoretical sciences, and create new academic disciplines, and social issues will be identified and resolved for the "integrative clarification of cosmos, matter and life," as one of the important subjects of basic science in this century. Specifically, this includes: 1) the coevolution of mathematics and natural sciences including the creation of new geometry, 2) the clarification of increasingly complicated biological function using mathematical method, 3) the clarification of origin of time space and matter using mathematical method, and 4) the investigation into machine learning technologies using mathematical science approaches. Also, domestic and international collaborative networks will be established for 5) the development of human resources who act beyond the framework of existing academic disciplines to improve brain circulation and contribute to creating innovation not only in scientific communities but also in industries using mathematical and theoretical sciences.

(3) Medical sciences

Medical sciences will be promoted for understanding high-order biological function and clarifying the mechanisms of functional collapse induced disease onset in humans for accurate and efficient prevention and treatment based on genomic and environmental differences between individuals.

Specifically, research for supporting the application of a breakthrough therapy to society will be promoted through 1) medical science research of genomic function to analyze the genome and understand its functions and diseases, 2) medical science research of human immunity to

clarify the processes of maintaining and collapsing constancy in human immune system, 3) medical science research of disease systems for collecting data, measuring and modeling environmental response of humans, and 4) clarification of human immune systems by combining researches from 1) to 3)to conduct basic research of cancer immunity leading to individualized cancer treatment, etc. In addition, leaders capable of pioneering new research fields in medical sciences will be developed.

(4) Bio-functional science

Multi-layered research including molecules, cells and individuals will be promoted with the aim of clarifying the principle of maintaining biological functions along the time axis ranging from generation and growth to aging and end of life of humans for contributing to realizing a society of health and longevity. This includes: 1) development of technologies enabling cellular status prediction and cell manipulation based on information obtained from the visualization of molecular and cellular status and non-invasive organ function measuring technologies, and application of these technologies to the prediction of health conditions and medical care, 2) clarification of organ formation and mechanisms of multi-organ alignment during formation, and methods of restoring damaged organs to develop the basis for next-generation regenerative medicine, as well as the development of medical examination technologies using non-/low-invasive measuring techniques, and 3) clarification of the mechanisms of maintaining healthy growth, development, maturity and aging of humans by inquiring into the mechanisms of controlling the progress of life cycle of living organisms based on researches 1) and 2).

Making good use of the comprehensive strength of RIKEN in bio-functional science, human resources capable of solving social issues with a broad view will be developed to contribute to the progress of this scientific field.

(5) Brain and neuroscience

Regions and structures controlling high-order cognitive functions characterized by human brain will be comprehensively analyzed and identified, and novel molecular machinery and operating principle that govern these regions will be clarified as well as the development of multiple brain measurement data analysis methods and biomarkers for building brain theory models and diagnosing mental and nerve diseases and developmental disorder by conducting: 1) research to clarify high-order cognitive function of human brains such as inference, self-reflection and reciprocity that make humans what they are using brain imaging and omics

analyses, 2) cross-layer brain research including molecules, genes, cells, circuits, systems, individuals and sociality based on animal models, 3) data driven type brain research led by theories and technologies, such as the development of brain measuring and big data analysis technologies, clarification of brain's calculation principle by accumulating data using these technologies, and development of brain type AI algorithm, and 4) research aiming at developing the methods of diagnosing and treating mental and nerve diseases, and supporting and expanding brain function. Accordingly, RIKEN will contribute to realizing a sustainable society to cope with a super-aging society, for example, by overcoming mental and nerve diseases to prolong healthspan.

RIKEN will also extensively conduct the world's best research as a core research center of brain and neuroscience in Japan in cooperation with research institutes, universities and industries in and out of Japan, and promote efforts for developing human resources expected to lead next-generation brain and neuroscience and expanding and returning research outcomes to society.

(6) Sustainable resource science

The research in this field will contribute to solving global issues, such as resource depletion, climate change and food insecurity by promoting interdisciplinary research combining plant science, microbiology, chemistry and data science, etc. for creating and using bio-resources and chemical resources with less environmental load.

Specifically, this includes: 1) research of innovative plant biology aiming at functional advancement of plants for sustainable food and biomass production, 2) research of metabolic genome engineering science for producing useful materials using plants and microorganisms, 3) advanced catalyst function engineering and research dealing with high-order function recycling catalysts for using earth resources, 4) research of new functional polymers including the synthesis of high polymer materials having useful functions, and 5) development of advanced technology platforms to support the above researches. In addition, efforts will also be focused on the development of outstanding human resources in sustainable resource science and raise scientific and technological standards.

(7) Emergent matter science

Integration of three fields of science developed independently so far, i.e., strong correlation physics, super-molecule chemistry and quantum information electronics, will be accelerated

based on the concept of emergent matter science. Relevant research includes: 1) energy functional emergent matter for creating and transporting innovative energy, 2) emergent functional soft materials for use in soft robotics having good affinity with humans, 3) quantum information electronic technologies useful for realizing quantum computation technologies and physics prediction for ultrahigh speed and high efficiency information processing at low power consumption, and 4) topological spin electronics for realizing energy saving electronics. The establishment of a new doctrinal structure and development of proof of concept devices to implement innovative hardware will contribute to realizing an environment-conscious, sustainable society, and promoting human resource development.

(8) Advanced photonics

The most advance optical and quantum technologies will be subject to research including: 1) extreme photonics for implementing technologies to generate, control and measure ultrahigh-precision laser and extremely-short pulse laser with the aim of applying these technologies to materials science and geodesy, 2) sub wavelength photonics for industrial application of precision work and ultra-microscopic optical measuring technologies by combining microscopic measuring technologies and laser processing techniques, 3) terahertz lights for functional control and matter creation by developing original terahertz photic oscillation and measuring technologies, and 4) development of advanced photonics technology platform including the development of non-destructive infrastructure measuring technologies, laser measuring technologies and special optical elements, etc. for applying the most advanced photonic technologies to society, thereby solving important social issues. Efforts will also be focused on the development of human resources expected to lead next-generation photonics science and raise scientific and technological standards.

(9) Accelerator science

Scientific principles of physical law governing atomic nuclei and elementary particles will be pursued at the RI Beam Factory (RIBF) which is the accelerator research base, and the Brookhaven National Laboratory (BNL) in the U.S. and Rutherford Appleton Laboratory (RAL) in the U.K. based on international cooperation. Accordingly, efforts will be undertaken for: 1) upgrading and sharing of accelerator facilities at RIBF, production of ultimate nuclear images, development of nuclear synthesis technologies, and clarification of element synthesis processes in space, 2) basic nuclear research, and 3) particle physics research based on international

cooperation with BNL and RAL. Also proceeded is 4) interdisciplinary application research using heavy ions and RI beams. The aim is to develop atomic nuclei and elementary particle physics and foster outstanding human resources including those for interdisciplinary application research. The operation of RAL facilities will be terminated during the period of this medium-term plan.

3 Promotion of development, maintenance, sharing and application of the world's best research infrastructure

Complementary collaboration with external institutions will be promoted by steadily developing and implementing research infrastructure including the world's best large research facilities, and sharing these facilities with internal and external researchers under the administration system governing the entire RIKEN according to the operations provided in Article 5 of the Act on the Promotion of Public Utilization of the Specific Advanced Large Research Facilities (Act No.78 of 1994) excluding the use promoting work by the registered institution for facilities use promotion. The research infrastructure for collecting, storing and distributing biological resources (bio-resources) commonly required in life sciences will be developed along with application research of bio-resources.

Research details are covered in appendixes.

(1) Computational science

RIKEN operates supercomputer "K" effectively and promotes the development of post "K" as a leading R&D institute for computational and computer sciences in Japan. It will strive for smooth transition from "K" to post "K" and shared use with researchers (1) sharing and more extensive use of "K" and post "K". Technologies and software developed so far will be included in the "core competence in computational science to drive sciences," and further developed for dissemination in and out of Japan by promoting the creation of outcomes to establish a core international research center in international computational science (2) launch of a core research center in computational science with the core competence. A system promoting computational science will be established in the agency and effective use of computational resources owned by the agency discussed.

(2) Synchrotron radiation science

Use of large-scale synchrotron radiation facility (SPring-8) and X-ray free electron laser

facility (SACLA) will be promoted through stable operation and extensive availability for researchers. Each of them will be constantly enhanced for maintaining world-class excellence as a single facility, and R&D resulting in the synergetic effects of both facilities will be promoted. In this context, four themes will be undertaken: 1) development of next-generation X-ray image detectors and high-speed and large-capacity data processing technologies, 2) development of cryo-electron microscopes and high-performance NMR for promoting comprehensive structural science research, 3) nano evaluation of commercial materials by improving X-ray energy analysis technologies, and 4) SPring-8 upgrading plan and R&D of required element technologies. This will contribute to the progress of R&D in a wider range of scientific fields, and through the development and application of these themes, sharing and application of facilities in industries, academia and government will be increased. Human resources will also be developed through the interchange of a wide variety of people, which will in turn contribute to the continuous creation or acceleration of science, technology and innovation.

(3) Bio-resource research

Bio-resources are essential materials for research in a wide range of life sciences and industrial activities, and required to develop strategically and systematically as a critical intellectual infrastructure to promote science, technology and innovation.

RIKEN will, as a core research center in Japan, conduct 1) the world's best bio-resource development projects for understanding accurate research trends and responding to social and research needs, 2) core technology development projects to develop preservation and application technologies for effective and efficient administration of bio-resource development projects, and 3) bio-resource related R&D programs for meeting research trends and needs. In addition, focus is also placed on the development of human resources dealing with bio-resource projects as well as the technical training and dissemination activities for transferring technologies to research communities.

Through the comprehensive efforts mentioned above, RIKEN will strive to publish xx papers every year for research outcomes. It will also strive to create high standard R&D outcomes with the aim of ~~~ as the index of being cited for published papers. <Under discussion on the proportion of highly cited papers including the correction of fields>

<Under discussion in light of field corrections including the rate of highly cited papers>

II. Measures for achieving the objectives of efficient operation and management

1 Streamlining and improving efficiency of operational expenses

RIKEN will continuously strive to make operational expenses more rational by reviewing required operations, streamlining procurement, and assuring efficient operational systems, and improve the administration of operations while making the best use of inventiveness.

For the projects funded by operational expenses grant, the efficiency of the total sum of general administrative expenses (excluding personnel expenses, special expenses and taxes and public dues) and operational expenses (excluding personnel expenses), excluding newly added, expanded and special expenses (e.g. xx), will be improved by xx% or more on an average in every accounting year. <Under discussion> The newly added and expanded expenses will be contained in this calculation from the next fiscal year. The state of the outstanding obligation of operating expenses grant will be taken into consideration in estimating the amount of operating expenses grant for every fiscal year.

Sustainable environment will be assured by constantly striving for saving energy, conserving heating, lighting and water, and curving emissions of carbon dioxide even under the demand for constraining the use of electricity. Efficient use of resources will also be focused by using limited research space more effectively under the system of adjusting the research space allocation throughout the agency.

2 Appropriateness of personnel expenses

Development of human resources having internationally outstanding capability will be assured for implementing projects especially requiring the world's best expertise and experience as those conducted by a designated national R&D agency based on the government policies such as the "Basic Policy for the Promotion of Research and Development by the Designated National Research and Development Agencies" (decided by the Cabinet on June 28, 2016).

For the wage level of administration and technical staff, engaging in general services accomplished by RIKEN, the qualification, assignment and age composition will be sufficiently reviewed, and their categories as national public officers, personnel organization, positions, locations of work, and academic background, etc. will be verified and compared with those of the employees of counterpart private enterprises. The public consent on the wage level of staff will be investigated, and if there is no rational reason for maintaining the wage level, necessary measures will be taken, and verification processes and measures will be made public.

3 Streamlining of procurement and appropriateness of contract

Considering that R&D is conducted in international competition, contracts will be concluded promptly and effectively, and a system required for suitable contracting processes will be established. General competitive bidding or other competitive contract procedures will be employed in principle, and fairness and transparency will be assured based on the “Policy for Streamlining Procurement by Incorporated Administrative Agencies” (decided by the Minister for Internal Affairs and Communications on 25 May 2015), and if discretionary contracts are inevitable, preliminary review will be conducted and the reason published. Required performance of procurement will be guaranteed, and the quality and prices will be well balanced according to the efficient and effective contract methods suitable for R&D characteristics. At the same time, the provisions mentioned above will be made clear to all employees across the agency, and their awareness will be investigated to take necessary measures.

Auditors or accounting auditors will completely check the appropriateness of bidding and contract during audits.

III. Measures for achieving improvement of financial conditions

1 Budgets (including estimate of personnel expenses), income and expenditure plans and fund plans

<Under adjustment>

2 Acquisition of external funds

Acquisition of external funds brings new ideas and horizons of research to in-house researchers, and leads to the creation of innovation in Japan and solutions for global issues by conducting R&D for resolving critical social and industrial issues in collaboration with universities and private enterprises. Acquisition of external funds will be accelerated further by understanding science, technology and innovation policies and industrial trends as well as proposing efforts to be prioritized in future and new projects through exchanging opinions with ministries and offices, private enterprises and organizations.

3 Limits of short-term borrowing

The limit of short-term borrowing is xx hundred million yen. <Under discussion>

Presumed reasons:

• Delay of acceptance of operating expenses grant

• Tentative disbursement of expenses relating to contracting work, etc.

4 Plans for unnecessary or potentially unnecessary assets

There are no plans for unnecessary or potentially unnecessary assets.

5 Plans for disposing or collateralizing important assets

Muon research at the RAL based on the research cooperation agreement in 1990 will be terminated in the mid to long-term objective period, and the assets which are no longer necessary will be disposed during this period.

6 Usage of surplus account

Surplus arising from settlement of accounts will be allocated to:

• Expenses relating to prior R&D

• Expenses relating to energy measures

• Expenses relating to intellectual property control and technological transfer

• Expenses relation to the improvement of staff qualification

• Expenses relating to the development of research environment

• Expenses relating to public relations

7 Debt burden exceeding the mid to long-term objective period

Debt burden exceeding the mid to long-term objective period will be accepted when the research infrastructure development exceeds the mid to long-term objective period and said debt burden is judged as rational in consideration of necessity and effects on the fund plan.

The following will be implemented as PFI projects:

(Private Finance Initiative projects)

• Development of the headquarters and administration offices

8 Financial reserve and usage

When financial reserve is left in the final fiscal year of the preceding mid to long-term objective period after processing pursuant to Article 44 of the Act on General Rules of Incorporated Administrative Agency, the amount approved by the competent minister will be

allocated to the following (financial resources for operations specified in the Act on RIKEN):

- Expenses relating to prior R&D specified as the use of surplus in the mid to long-term plan, expenses relating to energy measures, expenses relating to intellectual property control and technological transfer, expenses relating to improvement of staff qualification, expenses relating to development of research environment, expenses relating to public relations
- Account processing relating to the amount equivalent to undepreciated balance of fixed assets obtained from self-generated income
- Payment of consumption tax generated in the mid to long-term objective period out of the consumption tax refunded during the preceding mid to long-term objective period

IV. Other important matters concerning the administrative operations

1 Enhancement and strengthening of internal control

In regard to the promotion of internal control, each division will report the progress of internal control promotion, and corrective measures or recurrence prevention will be taken as required. A response plan for risks, which are obstructive factors against the accomplishment of objectives, will be launched and results of implementation will be analyzed or evaluated for risk control.

Internal audits will be conducted efficiently and effectively at each research center or by theme, according to the audit plans from medium-term perspectives, in addition to annual audit of contract and accounting departments. In addition, audit function will be strengthened by maintaining administration systems to assure the effectiveness of auditors, and providing assistance for flexible and professional audits.

2 Legal compliance and maintenance of the ethics

Research misconduct and illegal use of research funds will be prevented by complying with national guidelines. Awareness of researchers for research misconduct will be improved by conducting adequate training for assuring sound research activities based on the action plans for preventing recurrence. Efforts for operating a system to ensure the reliability of papers will be steadily promoted. Actions to prevent research misconduct will be made public.

To ensure a sound working environment, trainings will be conducted to prevent harassment and consultation desks to receive reports from staff will be provided for prompt and suitable response to the staff inside and outside the agency.

3 Securing safety in work

Safety will be sufficiently taken into account during work in compliance with the related laws and regulation.

4 Promoting information disclosure

Information disclosure will be further promoted pursuant to the Act on Access to Information Held by Independent Administrative Agencies (Act No. 140 of 2001).

5 Improving information security

An organization for ensuring information security in the research and administration divisions and comprehensively managing activities for information ethics training and compliance will be operated to meet the requirement of improving information security (particularly cybersecurity measures). A secure information system platform and information environment will be assured continuously to fundamentally reinforce the information security while latest technologies for cybersecurity measures are applied.

6 Matters concerning facilities and equipment

It is essential to continuously improve and maintain a good research environment at all times to improve R&D standards and develop RIKEN as the world premier R&D center. Accordingly, effective use of existing research facilities and facilities and equipment scheduled to be developed in the mid to long-term objective period will be promoted, including systematic modification, upgrading and maintenance such as measures to mitigate aging. It should be noted that maintenance, modification or upgrading of facilities and equipment may be added, required for the R&D to accomplish the mid to long-term objectives or in response to safety measures required to mitigate the aging of facilities.

7 Matters concerning personnel affairs

Retention of outstanding human resources including those having expertise, suitable assignment of administration staff, and improvement of staff qualification will be promoted for efficient and effective administration and operation. Mobility of researchers will be improved to vitalize and efficiently promote research activities by the use of fixed term staff and cross-appointment system.

<Appendix>

2 Promotion of strategic R&D based on national and social demands

(1) Advanced intelligence projects

1) Generic technology research

A broader range of basic research will be conducted to establish new core technologies for AI, etc. based in part on arguments in major international meetings.

Specifically, the performance and efficiency of deep learning, which have achieved remarkable results recently, will be improved by promoting theoretical clarification of the principle through basic mathematical research on deep learning models. New core technologies for generic machine learning will be developed through basic research of mathematical optimization, statistical learning theories and algorithms to find solutions for difficult problems the current deep learning cannot answer.

2) Goal-oriented technology research

R&D for establishing an analysis system, equipped with core technologies such as AI, will be promoted in collaboration with universities and research institutes to accelerate scientific research and find solutions for various problems in the real world.

Specifically, regenerative science and medical application, superfine manufacturing techniques, and development of functional materials, which are scientific fields Japan has international competitiveness, will be further reinforced. And, an analysis system equipped with AI and other core technologies will be established to find solutions for social issues in Japan including technological innovation in medical and nursing cares, disaster management and mitigation systems, maintenance and management technologies for aging infrastructure.

3) AI research in society

Actions to take for countering problems such as ethical considerations of relationships between AI and humans, what the legal system should be, and distribution of personal data including clinical history and genomic information will be proactively discussed by the parties concerned including researchers of humanities and social sciences, as the effects of progress and dissemination of AI technologies on society, and information will be distributed through international meetings to form global consensus.

4) Human resources development

Direct participation of students, corporate researchers and engineers in project through collaboration with universities, research institutes and private enterprises will accelerate human resource development on research site, and raise technological standards across Japan. In

addition, researchers with international perspectives will be developed by promoting personnel interchange with overseas universities and research institutes.

(2) Theoretical and mathematical sciences

1) Coevolution of mathematics and natural science

Interaction between natural and mathematical sciences will be expanded to accelerate the coevolution of the two sciences for creating new geometry and finding solutions for critical problems in mathematics such as millennium prize problems by not only applying modern mathematics to natural science, but also giving new motivations from natural phenomena to mathematics.

2) Mathematical science and clarification of origin of life

Focus will be placed on the clarification of one of critical problems in the modern biology, "the evolution process of biological function." Principles of autonomy and homeostasis of cells, function produced in the process of generation and adaptability to environmental changes, etc. stemming from the contrivance of biological molecules such as genes and protein will be analyzed using mathematical methods, and clarification of processes of biological molecules to acquire biological function as a system will be promoted.

3) Clarification of origin of space-time and matters using mathematical methods

The origin of space-time and matters will be clarified in joint efforts of physics, computational science and mathematics. In particular, large-scale simulation of particles and atomic nuclei will be promoted for finding the origin of matters along with the data of accelerator experiments and space observation in and out of Japan. Mysteries of space-time creation in black holes and at the beginning of space will be challenged by integrating modern mathematics, particle physics and space physics.

4) Mathematical science and AI

Mathematical basis on the indefiniteness of conditions and results of proper functioning of machine learning technologies will be clarified. Machine learning technologies will be applied to basic research of physics, chemistry, biology, and other disciplines to look for the possibility of new and novel discoveries. At the same time, the basis of machine learning technologies will be mathematically explored for establishing a concept surpassing the present deep learning technologies and designing mathematical algorithms that enable deep learning to make good use of its capability with a small amount of data.

5) Human resource development beyond sectors and layers

An international brain circulation network will be established for mathematicians, theoretical physicians, theoretical biologists, information scientists and computational scientists in Japan and abroad to tackle problems in close collaboration, and develop young human resources who will bring breakthroughs with mathematical science based novel ideas beyond the existing fields of science.

(3) Medical sciences

1) Medical science research of genomic function

Genomic analysis will be studied to understand genomic function and diseases. Technological development will be promoted for comprehensively analyzing gene expression and function of a variety of human cells using functional genomics. Developed technologies will be used for systematically understanding cellular regulation by regulatory RNA, and analyzing the genomic function of multi-level diseases to clarify disease onset mechanisms. A large-scale statistical analysis will be conducted to clarify disease onset mechanisms that break homeostatic function of various cells and tissues beginning at the human genome, and identify new disease and medication related to genes which have been left unresolved. The insights obtained will contribute to the genome-based drug discovery and genomic medicine with differences in individuals and side effects taken into account.

2) Medical science research of human immunity

Processes of maintaining and breaking homeostasis in human immune systems will be clarified. Differences between the two will be verified by human immune function research methods; the omics analysis that include homeostatic system research methods mainly on immunity using experimental animals, and the proteomics focusing on the non-uniformity of human groups which is difficult to analyze with experimental animals. Differences in immune systems between humans and animals will be verified using humanized mice to concatenate data of humans and experimental animals. Insights obtained will contribute to the efficient understanding of human immune system status and clarification of disease onset mechanisms.

3) Medical science research of disease systems

High-order, environmental response mechanisms via the interaction of organs in immune system, nervous system and endocrine system will be studied to understand the mechanisms at cellular and molecular levels. Technologies developed include measuring technologies for understanding multi levels of chronic inflammation such as dermatitis and diabetes, data integration for creating mathematical models, and technologies for experimental verification of

models. In addition, human disease models will be created by collecting multi-level, time series data at cellular and molecular levels from experimental animals and humans, modeling disease onset processes at organ and individual levels. Actual human-derived data will be applied to the created human disease models in cooperation with the Medical Science Innovation Hub Program, etc. for identifying new therapeutic targets or disease markers.

4) Basic research of cancer immunity

Cancer immunotherapy which has come under increasing notice as a therapeutic method for cancer caused by broken homeostasis of immune systems will be studied. Latent immunogenicity of tumor such as neo-antigen and mechanisms of the occurrence of immune system cells inside and outside of tumor will be clarified at gene level using single-cell omics analysis technologies. Insights obtained in this research and those in 1) to 3) will be integrated for comprehensively understanding disease onset mechanisms and stratifying at gene level. Basic and transitional research will be further promoted in a comprehensive manner to extract more effective target cells for cancer treatment.

(4) Bio-functional science

1) Visualization, prediction and manipulation of cellular and molecular status

Research focusing on a broader range of life stage will be conducted using experimental materials including embryonic stem cells, induced pluripotent stem cells and human cells. Data driven type approaches will be developed for integrating and analyzing a large amount of imaging data obtained from automatic robot experiment systems or new 3D high-speed, high-resolution microscopes of 300 nm of isotropic space resolution, 3D molecule architecture data and omics information with AI. With this, new technologies of modeling by predicting dynamic and detailed information of certain cells only using direct observation results will be developed. These technologies can be used for health status prediction by enabling non-invasive cytoscreening and prediction of cell status which was once difficult in conventional approaches. Cell manipulating technologies for differentiating and inducing target cells appropriately will be developed and applied to medical care.

2) Clarification of organ formation and multi-organ entrainment mechanisms

Research focusing on the connection of layers from cells to organs will be conducted. Target molecules for biological function will be searched, and technologies for visualizing all cells of organs and non-invasive imaging technologies will be developed. The results will be used for clarifying the principle of organ generation and regeneration in consideration of interaction with

ambient surroundings as well as organ formation mechanisms, organ function maintenance and reduction control and principle of functional recovery. Using research outcomes obtained, 3D organ formation technologies and next-generation regenerative medicine infrastructure will be developed with a view to transplantation. By developing and improving non-invasive imaging technologies for medical care and diagnosis, a basis for understanding human health conditions will be obtained for developing medical examination technologies.

3) Clarification of lifecycle procession control mechanisms of living matter

Research will aim to clarify the multi cell system control program common to humans and model animals, and mechanisms of adaptation to environment. Using technological development and clarification of principles in 1) and 2), processes from generation, growth, development to aging of humans will be modeled. Development, maintenance and recovery mechanisms of nervous networks will be clarified using this model, and factors of failure of organ function accompanying aging will be identified. Combining the insights obtained, mechanisms of maintaining and declining biological function at individual levels will be understood for realizing a society of health and longevity.

(5) Brain and neuroscience

1) Clarification of high-order cognitive function of human brains

Analysis combining high spatiotemporal resolution brain imaging, physiological measurement and brain stimulation in cognitive problem handling, and brain omics analysis methods will be used for clarifying high-order cognitive function including prediction, self-reflection and reciprocity, all of which are highly developed in humans.

2) Vertically integrated research based on animal models

To understand brain nervous systems in which multiple layers from molecules to individuals and sociality interact, the existing single layer research will be expanded to research of all layers to clarify the principle of human brain operation beyond layers.

3) Data driven type brain research led by theories and technologies

High resolution and low invasive measuring technologies and technologies to track down function in various brain layers will be developed, and mass data containing comprehensive and real-time analysis of the whole brain operation will be accumulated. In collaboration with AI and mathematical science research, a brain operation theoretical model will be created from the mass data for supporting next-generation AI development.

4) Development of diagnostic and therapeutic methods for mental and nerve diseases and

assistance to and expansion of brain function

Commonality and diversity of pathological conditions will be clarified by understanding brain nervous systems acting as a contact between mind and biological homeostasis mechanisms, and new diagnostic and therapeutic methods for depression, dementia, developmental disorder and other disorders will be developed in addition to the clarification of intrabrain mechanisms such as emotion, sociality, learning and sensitivity, and development of supplementary technologies for brain and body function to provide the seeds of innovation useful for daily lives.

(6) Sustainable resource science

1) Innovative plant biology

Control factors and compounds critical for adaptation to environmental stress, disease resistance, coexistence, matter production and resource use will be identified and utilized using leading-edge research and technology infrastructures for the stable supply of food and biomass to cope with global climate change, and technologies for improving plant characteristics will be developed for use in agricultural fields. Data on interaction between living matter and environment will be analyzed for optimizing the selection of genetic lineage, ambient conditions and cultivation methods, etc. to improve characteristics of farm products and increase productivity.

2) Metabolic genome engineering

Development includes new chemical industries which make the most use of chemosynthesis capability of plants and microorganisms with less environmental load without using fossil resources, and production systems for useful materials used for raw materials of pharmaceuticals. Information technologies including AI and genome science will be applied to collect gene and metabolism related information for enabling biological production of industrial materials with microorganisms and plants as the host and independent of chemical compounds and fossil resources which are difficult to raise efficiency in conventional chemosynthesis. This allows the development of sustainable and innovative technology platform for developing production systems independent of fossil resources and omnipresent biological resources.

3) Advanced catalyst function engineering

High function recycling catalysts will be developed using air resources, water resources and crustal resources for stable supply and cyclic use of environmental resources.

This includes effective use of carbon dioxide and oxygen in developing useful materials, catalysts for activation and effective use of nitrogen molecules, metal catalysts useful for

water-splitting reaction leading to hydrogen production, and biomimetic catalysts functioning under the water. In addition, catalysts using cheap and abundant crustal resources and various metallic characteristics will also be developed to create functionalized molecules.

4) New functional polymers

Technologies for designing molecules of new functional polymer materials, which may bring innovation to chemical industry, will be developed to improve resource usage efficiency and create new industries.

Using molecular catalyst technologies, unprecedented synthesis technologies will be developed for highly selective, efficient and precise polymerization of olefin monomer groups. In addition, technologies of synthesizing high heat resistance new polymer materials from bioorganic compound groups, and high function peptide polymer materials using biotic and enzymatic catalysts.

5) Advanced technology platform

To support and promote above four projects, namely, “innovative plant biology,” “metabolic genome engineering,” “advanced catalyst function engineering” and “new functional polymers,” a measuring and analysis technology platform using data science, and a cross-cutting information infrastructure to support the analytic technologies will be developed and enhanced.

(7) Emergent matter science

1) Energy functional emergent matter

Strong correlation physics research and supramolecular function chemical research will be combined and developed to enhance energy collection and conversion function such as thermoelectric conversion at wide temperature range using theoretical and experimental approaches as well as enhancement of generating efficiency of solar batteries, and create innovative energy and implement the transportation function by designing high temperature superconducting materials and searching materials extensively using AI technologies.

2) Emergent functional soft materials

Supramolecular function chemical research will be promoted to develop soft actuator materials using new power generation mechanisms, and search new principle and develop materials for creating and sensing chemical and environmental sensors having good affinity with humans. In addition, flexible devices will be developed using organic semiconductor materials to support the development of soft robotics.

3) Quantum information electronic technologies

Quantum computing technologies capable of processing information highly efficiently at ultrahigh-speed and low power consumption will be achieved by developing quantum information electronics research thereby developing integration technologies aiming at 50 qubits and control technologies with more than 99% precision of quantum bit gate consisting of electronic spins in superconducting quantum circuits and quantum dots for mounting quantum computing algorithms. Superconducting quantum circuits, cold atoms, spin-based simulation technologies and devices will be developed to support physics prediction.

4) Topological spintronics

Energy efficient electronics will be promoted by developing strong correlation physics research and quantum information electronics research simultaneously, thereby producing proof of concept devices to achieve spin and electron transportation without energy loss using topological materials such as skyrmionics for search of multiferroics materials (having both ferromagnetic property and ferroelectricity) and explore application theory using new emergent particle skyrmion, and topological insulator (insulator inside but metallic state on the surface).

5) Human resource development

Laboratories led by young researchers will be launched for developing PI human resources under the mentorship of senior researchers in collaboration with universities in and out of Japan. Taking advantages of characteristics of the research center, interdisciplinary symposiums, involving physics, chemistry, quantum and other scientific fields and focusing on young researchers, will be held to provide opportunities for presentation and discussion and an environment nurturing wider knowledge and view. Young human resources in industries will be proactively accepted for participating in the world's most advance research in cooperation, improving the research capability of both industries and RIKEN and ultimately scientific capability of Japan.

(8) Advanced photonics

1) Extreme photonics

RIKEN original ultrahigh-precision laser control and ultrashort pulse laser generation and measuring technologies accumulated so far will be developed further to visualize various things and phenomena that cannot be directly observed at present, and efforts for attosecond pulse generation at sub-kilo electron volt, much stronger than the conventional power, and portability of optical lattice clock for commercialization will be applied to material science and geodesy.

2) Subwavelength photonics

RIKEN original laser processing technologies and super-resolution microscope measuring technologies exceeding the optical diffraction limit will be developed further and combined to develop pseud-biometric chips having nano-scale structure and function in excess of the conventional optical limit and super-resolution 5D microscope imaging technologies enabling the observation of deep inside the living body, and commercialization of these technologies will be promoted.

3) Terahertz lights

RIKEN original terahertz light oscillation and measuring technologies and device technologies accumulated so far will be developed further to promote research using high operability specific to lights in a microscopic energy area of milli-electron volt, and apply it to a wide range of industries. This will pioneer new sciences such as functional control and material creation using high intensity terahertz lights. Application to imaging and spectral nondestructive inspection may be considered.

4) Advanced photonics technology platform development

Smaller and lighter models of the small neutron source system will be developed for producing portable systems and enhancing technologies to conduct nondestructive inspection on outdoor infrastructure. RIKEN original wavelength-tunable, extremely-short pulse laser technologies will be developed further, and laser measuring and other usage dependent utilization technologies will be promoted. Special optical elements will be developed using manufacturing (monozukuri) technologies based on most advanced microfabrication technologies.

(9) Accelerator science

1) Enhancement and sharing of accelerator facility in RIBF

Longest possible time of operation of the facility will be intended to create outcomes from the world's most advanced RIBF. The intensity of beams will also be improved. In particular, the intensity of uranium beam will be increased to around 100 pnA for extensive application to unexplored zones. A high power proton beam plan will be launched to increase beam intensity 10 to 20 times by reinforcing ion sources and high frequency systems in addition to constructing a new accelerator. At the same time, distinguished utilization themes will be selected and collaboration with research institutes in Japan and abroad reinforced.

2) Basic nuclear research

The basic experimental equipment group, scheduled to be newly put in full-scale operation,

will be used to a maximum extent to create an ultimate nuclear image, including the element synthesis of Nos. 119 and 120, magic number research, state equation research, element transformation reaction research, and nuclear synthesis technologies for achieving the "island of stable nucleus" in future. The basic nuclear research will further be expanded, for example, to the clarification of element synthesis processes in space by combining nuclear theory research, astronomical observation and the Antarctic ice sheet core analysis.

3) Particle physics research based on international cooperation with BNL and RAL

The detector developed for the Relativistic Heavy Ion Collider (RHIC) of BNL will be modified for the complete measurement of jet shaped particle generation. With this experimental research and lattice quantum chromodynamics numerical simulation, the spin structure of proton and nature of high-temperature, high-density nuclear materials will be clarified.

The Muon detecting device installed in the proton accelerator (ISIS) of RAL is used for studying the expression mechanisms of properties of new functional materials, including superconductivity, magnetism and insulation. The operation of this facility will be terminated during the period of this medium-term plan, and users will move to other plans. RAL and RIKEN will jointly operate the experimental equipment until the end of operation, and dispose unnecessary assets upon termination.

4) Interdisciplinary application research using heavy ions and RI beams

Heavy ion beam breeding technologies, RI manufacturing technologies, industrial product resistance evaluation technologies, etc. will be enhanced to meet social and industrial needs for supporting to find solutions for food, environmental and energy issues, and production of nuclear pharmaceuticals for cancer diagnosis and treatment as well as semiconductors for space use.

3 Promotion of development, maintenance, sharing and application of the world's most advanced research infrastructure

(1) Computational science

1) Sharing and extensive use of "K" and post "K"

RIKEN will operate supercomputer "K" effectively, and promote the development of post "K" as the leading R&D agency in computational and computer sciences in Japan. Transition from "K" to post "K" must be smooth for common use by researchers. "K" will be operated more than 8,000 hours every fiscal year except for the transition period, and its computational resources

provided for researchers exceed 663,552,000 node-time (82,944 nodes × 8,000 hours). Post "K" will be operated for around the same time as "K" to offer many computational resources to researchers. Efforts include the establishment of common base technologies to support research activities using "K" and post "K," research of enhancing utilization, development of the world's best operation technologies, as well as increase of users, and improvement of usability and promotion of human resource development in suitable role sharing and collaboration with registered facility utilization promotion organizations and other related organizations. Activities regarding post "K" will be started based on the interim assessment by the government and discussions at the High Performance Computing Infrastructure Consortium.

2) Formation of core centers for computational science based on computational core competence

Technologies including data assimilation that will be the core of creating new value in science and technology and RIKEN has advantages, big data analysis and automatic massive parallelization, and software developed by RIKEN and contributing to science, technology, industries and society will be classified as the "core competence in computational science to drive sciences" and their development and dissemination in and out of Japan will be promoted as well as creation of outcomes to form core centers for international computational science.

A system for promoting computational science research will be formulated in the agency, and R&D conducted for data science and future high performance computation technologies of which importance is increasing. Investigation will be made for the effective use of computational resources in the agency.

(2) Synchrotron radiation science

1) Improvement of utilization environment by developing measurement instruments and analysis equipment

Development and enhancement of measurement instruments and analysis equipment as well as the improvement of utilization environment will be promoted to create groundbreaking outcomes from SPring-8 and SACLA. Specifically, next-generation sensor will be developed to achieve dramatically large enhancement of a wide range of X-ray measurement with high-speed, high-precision and bulk measuring data. Development of high-speed, on-time bulk data processing technologies will be promoted, allowing the improvement of data quality with real-time, high-speed data correction and on-time data analysis technologies, and implementing high-speed processing of bulk data obtained from next-generation sensors.

2) Promotion of comprehensive structure science research by development of cryo-electron

microscope and high-performance NMR

Technological development will be conducted on cryo-electron microscope which is a complementary structural analysis method with radiation lights, and high-performance NMR. Specifically, detectors of next-generation cryo-electron microscope will be developed to visualize information closely relating to biomolecular function, and the range of application will be expanded to critical membrane protein in terms of life science. Probes of next-generation ultrahigh-performance NMR will be developed, and application will be expanded to greater molecular systems such as amyloid.

3) Nano evaluation of actual materials with more sophisticated X-ray energy analysis technologies

Nondestructive imaging of elemental information in the actual materials such as lithium ion secondary batteries and ultra-lightweight, high-strength structural materials will be made possible during operation using the anelastic scattering measurement of hard X-ray zone. Visualization of function will be achieved while high resolution is maintained by introducing sophisticated X-ray mirror technologies. This is promoted as an analysis tool for actual materials.

4) SPring-8 update plan and R&D of required element technology

Accelerator element technologies developed so far will be assembled to verify system design for upgrading SPring-8 facility. Automation of accelerator and beam line operation, development of element technologies for next-generation X-ray optical systems like mirrors, and design and development of pilot beam lines based on the first new concept in the world will be promoted.

(3) Bio-resource research

1) Bio-resource maintenance project

Most advanced bio-resources and information will be collected, stored and distributed to accurately understand research trends, and promptly respond to social and research needs. The project includes laboratory animal model (mouse), experimental plants, human and animal derived cell strain like iPS cells, cultured myocardial cells, and gene stock derived from these cells, and achieves the following targets:

	No. of preserved samples	Total No. of samples
Experimental animals	9,700	17,500
Experimental plants	838,300	8,400
Cellular materials	14,200	23,100
iPS cells	3,587	560
Genetic materials	3,809,450	7,000
Microbial materials	30,150	21,000

Strict quality inspection will be carried out based on the international quality management standard to supply the world's best bio-resources of quality that guarantees the reproducibility of research outcomes, and with various types of information for facilitating utilization. Backup facilities will be built and operated to prevent loss of valuable bio-resources during large-scale disasters. For assuring the international superiority of Japan in bio-resources and maintaining international cooperation, RIKEN will participate in various international initiatives relating to the maintenance of bio-resource.

2) Core technology development project

For stable and efficient bio-resource maintenance, R&D particularly for improving and disseminating technologies for freeze preservation, transportation and recovery in vivo of mouse resources, improvement and development of embryo manipulation technologies and enhancement and homogenization of stem cells will be promoted.

3) Bio-resource related R&D programs

For solving scientifically important issues such as higher order biological phenomena, aging and coexistence, and pressing social issues like cure of serious illness and age-associated diseases, drug discovery and increase in food production, R&D to promote bio-resource utilization will be promoted. Development of accurate differentiation-inducing techniques for iPS cells, basic research like optimization, and technological assistance to universities and private enterprises will be promoted to accelerate pathological and drug discovery research. RIKEN will contribute to clarifying the function of all genes and the effect of aging on phenotype as a major member of the International Mouse Phenotyping Consortium. Disease mouse models that reproduce the genetic type and clinical condition of patients will be produced and expanded to the maintenance operation. The actual condition of coexistence of plants and microorganisms will also be clarified and make them recyclable.