A journal of original papers of *Type Two Basic Research*

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A new journal entitled *Synthesiology* is now being published by the National Institute of Advanced Industrial Science and Technology (AIST). The path to the publication of this journal was not easy. Long hours of discussions were held among the members of the editorial board concerning the nature of the journal, and I believe its general direction and philosophy are gradually taking shape. Here, I would like to express my thoughts on this new journal.

Synthesiology is a collection of papers on the results of Full Research, especially Type 2 Basic Research. Full Research is a term used at AIST to indicate a research method that can effectively make contributions to industry. This research approach, however, has always been plagued by a fundamental problem. Although many important and original studies have been done, there has been no place where such researchers could exhibit their originality in the form of research papers. As a consequence, their original thoughts failed to become public property, and this has been a serious loss for society. Although this journal was born from the efforts of AIST researchers, I hope it will become a place of presentation for all similar research conducted around the world.

1 Foundation of the National Institute of Advanced Industrial Science and Technology (AIST) — Background of the Journal

The National Institute of Advanced Industrial Science and Technology (AIST) was founded in 2001 by the integration of 15 research institutes under the Agency of Industrial Science and Technology (the former AIST), including some member organizations that date back to 1882. Harboring 3,000 researchers, it is one of the largest independent administrative research institution in Japan. Moreover, it is a multidisciplinary institute covering wide-ranging fields including mechanical engineering, electricity, electronics, materials, chemistry, life science, information science, energy, environment, geology, and metrology. Its objective is to promote industrial progress through basic research and developmental research. The mission of the Geological Survey of Japan, the oldest research organization, was to explore the natural resources that were essential for Japan to develop in the Meiji Period. Not only did it carry out exploration, but it also carried out the necessary basic research in geophysics and chemistry, and applied the knowledge gained to actual resource exploration. The Central Inspection Institute of Weights and Measures also has a long history and has conducted research on physical standards and units, the most basis of scientific research, while at the same time carrying out practical tasks such as the calibration of measuring instruments. Looking back at the history of the research institutes of AIST that were established one after another, it is clear that all pursued basic scientific research while also providing the knowledge needed for industrial development required by Japan at the time.

Immediately before the foundation of AIST, there were 15 separate research institutes under the auspices of the Agency of Industrial Science and Technology, which was an affiliated agency of the Ministry of International Trade and Industry (the present Ministry of Economy, Trade and Industry, METI); eight research institutes dedicated to individual research fields situated in Tsukuba and seven regional research institutes. Each institute was devoted to a specific field with specialized researchers conducting basic research in their respective fields. At the same time, each institute was engaged in national projects with industry involvement. This system has contributed greatly to the industrial development from the founding of Japan in the Meiji Period to the industrial revival after World War Ⅱ, as well as to the increased competitiveness of the manufacturing industry which has lead to strong economic growth. After achieving strong economic growth in the latter half of the 1980s, the export volume of Japanese industrial products increased and Japan occupied a significant position in the world market. Many countries saw Japan as a country, however, that created products by applying basic technology developed in other countries, mass-produced highly competitive, high-quality, low-cost products using mass production technology, and conquered international markets while expanding its economy. This perspective aroused criticism from countries that were disadvantaged by the competition. This viewpoint, which has been sometimes referred to as a “free ride on basic research”, claimed that Japan never conducted basic research on its own, but borrowed basic scientific results obtained by other countries with great investment, applied them, and made a profit. This emotional condemnation became the

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basis of trade conflicts and put Japan in a difficult situation. Japan has made tremendous efforts both internationally and commercially to solve this conflict, and this also affected Japanese research policy. It has resulted in an emphasis on basic research, and greatly influenced research activities as a whole. The phenomenon is referred to as the "shift to basic research" at the institutes under the Agency of Industrial Science and Technology.

The shift to basic research was a major event in the history of scientific research in Japan, and detailed analysis and interpretation are due, although it is perhaps too early to reach a conclusion. Here, I shall discuss what can be said as of now. First of all, the "free ride" viewpoint is too extreme and diverts attention away from Japan's achievements. Furthermore, it neglects the application of scientific knowledge to societal needs. Basic research is essential as source of new industry. Yet, basic research alone is insufficient to benefit mankind. It must be developed into something to benefit people to have value to society. As exemplified by textile production using weaving machines invented during the Industrial Revolution, and by further mass production of motor vehicles in the United States, affluence is spawned from the use of scientific knowledge. Thus, production technology, which was the most important factor in increasing Japan's competitiveness during its period of high economic growth, should be understood as a process of progress. For example, along with the improved performance of manufacturing processes the environment in which workers can make full use of their intellectual, emotional, and technical potential enabled the production of high-quality, high-reliability, low-cost products. This production format has not only been adopted by developing countries, but is employed by the advanced countries of Europe and the United States as the primary method of increasing affluence today. Therefore, Japan should be proud as the inventor of this production format and not be ashamed of taking a "free-ride". Yet in reality, Japan has not been commended. Japan's contribution to the evolution of production technology did not occur by accident, but was an inevitable result of scientific and educational policies set forth by our forerunners at the beginning of the Showa Period. However, I shall not elaborate on this matter here. The first problem is misevaluation or the neglect of our production technology achievements by us as well as others.

The second problem is the way in which Japan has dealt with the confusion that arose from the trade conflict, although it should, in fact, be proud of its achievements. Individual companies have made efforts to shift to locally based production in foreign countries, and various policies and administrative directives have been undertaken. These policies included the removal of import restrictions and the implementation of procurement restrictions. These policies have also affected the scientific world. This meant a shift away from application and development, and a move toward the basics of scientific research. The same policies also promoted the import of research instruments. These changes did not necessarily mean an emphasis on basic research or prioritization of specific research disciplines, but simply meant a statistically significant increase in funds for basic research within the total research budget. In terms of total research funding, the capital investment by the private sector has always much greater than government expenditure. This tendency is still strong in Japan, although it has been stronger in the past, and this was the basis of argument that Japan neglected basic research. Therefore, it became necessary to assert that all state-funded research was basic research. As a result, all institutes under the Agency of Industrial Science and Technology were obliged to engage in basic research. This move was called the "shift to basics", and the emphasis on basic research gradually increased. For the sake of scientific development, basic research is important regardless of the time or circumstances. Therefore, this shift has raised the level of the institutes under the Agency of Industrial Science and Technology in terms of their ability to produce basic research results, and the knowledge accumulated remains valuable to this day. On the other hand, considering the historical mission of the institutes in promoting industrial development, this shift undeniably obscured the role of the institutes today. At the same time, other countries began seeking ways to use new scientific knowledge to develop industry in the 1990s, and set policies that systematically accelerated the use of scientific knowledge through academic-industrial collaboration and public projects. Thus, while Japan made efforts to avert criticism originating from trade conflicts that Japan was too good in using knowledge, the situation in the world has changed completely and there is now competition in the ways of using knowledge. This is a serious issue. The second problem is the fact that while Japan made the correct policy of emphasizing basic research, it unnecessarily put aside its skilled use of knowledge, which in itself does not contradict the need to carry out basic research on a national level. AIST was founded to solve this problem.

2 Full Research — Need for the journal

The integration of the various institutes of the Ministry of International Trade and Industry into AIST was a change made in response to the aforementioned problems. Simply stated, it was a realization of an institute that conducts basic research at international standards of excellence and contributes to actual industrial development. This has, in fact, always been the objective of the institutes of the Agency of Industrial Science and Technology since the Meiji Period, so the change was actually a return to its roots. However, considering the colossal changes in the situation that surrounded the institutes, rather than a simple return

to its origins, a new viewpoint was needed. For example, enterprises throughout the world are required to enhance their competitiveness by using original knowledge acquired through basic research. In the age of mega-competition, however, industry can no longer spare time for basic research. Instead, universities and public institutions are expected to conduct basic research to serve the needs of industry. This has become the style not only in Europe and the United States, but also in many developing countries. Japan needed its own agenda for change, and the integration of the institutes under the Agency of Industrial Science and Technology was part of this effort. This integration was a change in a true sense because it involved the integration of individual researchers rather than that of the organizations. Fifteen research institutes were dissolved, and 3,000 researchers were distributed into 60 new research units with specific purposes to make contributions to industrial technology. Researchers selected their affiliation by their industrial contribution rather than selecting institutes to which they formerly belonged. As a result, each research unit consisted of researchers from diverse fields. Researchers thus have been organized according to objective rather than field of study.

The research units are autonomous in conducting research and are operated under leadership of their unit directors. They are free to do any type of research but are required to have clear goals to make contributions to industry. They are expected to carry out basic research and to contribute to industry at the same time. Therefore, some researchers of the unit engage in basic research while others engage in industrial applications of the research (since 3,000 researchers were divided into 60 research units, the average number of researchers per unit is 50, but in practice there are units of various sizes ranging from 10 to 250 researchers.).

Traditionally, these two tasks are handled by researchers of different disciplines in separate organizations. Basic research is conducted by universities while product realization is done by private companies. Basic research is further divided into specialized fields, such as natural sciences and engineering at universities. There must be an effective relationship between basic research and product realization so that industry can reap the benefit of basic research. This is often accomplished by industry-academia cooperation, intellectual property licensing, and ventures, but it is commonly recognized worldwide that such attempts are not always successful. Basic research and commercialization may not be continuous. Cooperation between researchers of industry and academia is often difficult, and this has been long regarded as a problem, but has never been solved. The new research units at AIST are, however, required to simultaneously realize both basic research and industrial contributions. Here, general basic research is called Type 1 Basic Research. It is necessary to have a new group of researchers who merge the contents of Type 1 Basic Research to Product Realization Research. This new category is referred to as Type 2 Basic Research. Therefore in a research unit, there are three kinds of researchers: researchers of Type 1 Basic Research, researchers of Type 2 Basic Research, and researchers of Product Realization Research. The research collectively conducted by these groups of researchers is called Full Research.

3 Type Two Basic Research and knowledge — Mission of the journal

The new journal provides a place to publish the papers of Type 2 Basic Research and to exhibit the original thinking of the researchers. It is necessary, therefore, to define Type 2 Basic Research, but this task is not simple, and not completely possible as of now due to its diversity. Let us study the significance of the original Type 2 Basic Research papers by referring to the following definition that I presented in an article in which I discussed the matter in detail [1]. The definition of Type 2 Basic Research is as follows:

“A form of research that integrates the knowledge of different disciplines or creates new knowledge when necessary, and transforms a concept into artifacts (product or service) that can be recognized by society”

Such activity is nothing new since it has been done widely with new inventions and industrial product creation. Yet it has not historically been called “research”. Furthermore, it has never been called basic research. It is necessary therefore to consider this as a form of basic research referred to here as Type 2 Basic Research.

First, it is necessary to ask, “What is basic research?” If it can be said that basic research without an adjective has no purpose, a new category of purposeful basic research can be defined . Limiting the discussion to basic research in natural sciences, such research enriches the body of knowledge of natural science by creating new knowledge. Strictly speaking, the value of scientific knowledge depends on the kind of “enrichment” pursued, but researchers may not necessarily be aware of this concept, and research may “lack purpose” in this sense.

In general, although individual research carried out by a researcher only aims to enrich the body of knowledge, or in other words, is basic research not intended to be immediately useful in society, the knowledge acquired may become extremely useful for societal activities regardless of the intentions of the researcher. This is self-evident from the fact that almost all contemporary technologies are grounded in scientific knowledge. Thus, it can be said that the “basic” of basic research is the “base” that underpins real societal

activities. Real societal activities are not just technology. Basic knowledge acquired through basic research is the basis of all societal activities including politics, public administration, economy, finance, management, medicine, education, industry, production, and media. At the same time, it is fundamental to regard scientific knowledge created through basic research as public knowledge i.e. the collective property of society. This is the premise for the public funding of basic research. Today, basic research result sometimes becomes privately owned intellectual property, but this is only temporary. In general, research results are published in various specialized journals as research papers that are publicly recognized as the original work of the researcher who conducted the research. At this point, the knowledge becomes public property.

It is necessary to consider whether Type 2 Basic Research fulfills the fundamental requirements of basic research. The fundamental requirements are as follows: research results should refine or add to specific knowledge regarded as the collective property of society, and it should be useful to actual societal needs although individual research does not necessarily have to have immediate purpose. With these considerations, if we were to distinguish Type 2 research from general basic research, the Type 2 body of knowledge should be different from existing scientific knowledge. Here, general basic research is referred to as Type 1 Basic Research, and the body of knowledge consists of the scientific knowledge accumulated over history. The argument that the body of knowledge of Type 2 Basic Research is different from that of Type 1 Basic research is the basis for claiming the existence of two types of basic research. Therefore, it is now necessary to clarify the difference between the bodies of knowledge of Type 1 and Type 2 research.

The body of knowledge created by Type 1 Basic Research is knowledge of the actual world. The driving motive of research is a researcher's intellectual curiosity. Physics, for example, historically began as a study of the properties of the world around us, and has been successful in consistently explaining the emergence of matter, the dispersion of matter and its historical transition in the universe, and the properties of matter both on earth and in space. Explanations were initially limited to nonliving matter, but now are being applied to life as well. Physics has achieved great success in creating a consistent body of knowledge concerning the existence and behavior of all matter on earth as well as in the universe. Being consistent means, for example, that the explanation for the light originating from a light bulb nearby is consistent with the explanation for the light emitted by distant celestial body.

Physics, however, has not explained everything. Traditionally, the academic study of nature has included chemistry, biology, geology, meteorology, oceanography, and archeology, and if human beings are included in nature as study subjects, then there are also the fields of linguistics, psychology, anthropology, sociology, economics, and cultural anthropology. These varied fields are commonly referred to academic disciplines. Individual disciplines do not necessarily use common concepts, and in general, unrelated, different explanation may be given for the same topic. Therefore, it is necessary to state precisely what "mutually consistent body of knowledge" means. This consistency is valid only within each academic discipline, and the explanations are unrelated or mutually non-interactive rather than consistent between disciplines. However, a larger movement is emerging within the field of science, where physics is expanding its scope to interactions between matter and life and the demarcations between other disciplines such as chemistry and biology are blurring. In a similar way the topic of neuroscience hints at merging with parts of linguistics. Unity, however, will not be easily attained because the situation is complex and irregular, and it is unclear whether non-interacting areas will disappear.

Type 2 Basic Research can be considered as independent form of basic research by determining whether the research defined as Type 2 Basic Research has a unique body of knowledge created under its umbrella, and if so, whether that body of knowledge is essentially different from the aforementioned body of knowledge created by Type 1 Basic Research. It is important to seek out the relationship between the two bodies of knowledge in considering the relationship between science and society, but this will not be considered here. Simply stated, the body of knowledge of Type 1 Basic Research is, as mentioned above, a system that explains or provides understanding of all phenomena that we can experience by creating disciplines that are initially non-interacting and by slowly integrating these disciplines. The motivation of the research is intellectual curiosity. If this is defined according to the same terms used for aforementioned Type 2 Basic Research, it will be:

"Creation of new knowledge by using existing knowledge of a discipline that is consistent with the knowledge of that discipline".

Here, Type 1 Basic Research is mainly considered as "normal science" as described by Thomas Kuhn [2], but it should be pointed out that what Kuhn calls the "paradigm shift" is the integration of disciplines or the creation of new disciplines which are important but particular to his theory.

Both definitions concentrate on use of knowledge, but Type 1 uses the knowledge of a single closed discipline whereas Type 2 is not limited by discipline. In general, use of knowledge in a certain discipline is formulated by experiments or by a logical thinking process, but there is no formulated method for using knowledge in multiple disciplines. Moreover, the

output of Type 1 research is knowledge, while it is an artifact for Type 2 research. If the realized output is knowledge, its validity can be logically confirmed, but if it is an artifact, its validity can only be demonstrated by actual use in society. This brings forth the following distinctions:

(1) In Type 1 research, the researcher exercises originality in selecting subjects from the body of knowledge of a given discipline and in selecting the research method, experimental or analytic, appropriate for the discipline. In Type 2 research, the researcher must establish a knowledge subset without limitation by discipline, choose the method, experimental or analytic, that enables the use of knowledge from the diverse candidates, and integrate them into a meaningful whole.

(2) In Type 1 research, the realized output is knowledge, and good results are incorporated into the body of knowledge of each discipline. In Type 2, the realized output is an artifact and good results are put to use by society.

Looking at these distinctions, it should be noted that the difference is two-dimensional. First, the way of using knowledge is different, and this leads to different activities. Second, the significance of the realized results is different, and this is the difference of the recipient. The following table summaries this concept.

As it can be seen from the table, there should be four categories due to the two-dimensionality of the system, where items (A) and (B) are blank. This is a result of historical development where Type 1 Basic Research aims for the production of knowledge, while Type 2 aims to make a contribution to society. This is also the cause of segregation between society and academia and should be dissolved. In Type 1 Basic Research, currently there are great expectations for contributions to society, but merely providing knowledge is insufficient. Recently, this expectation has been met in the form of advisory contributions by diverse researchers such as climate change warnings in meteorology or bioethical advice in biology, and this is a supplement to (A). On the other hand, Type 2 cannot be called “basic research” if it does not affect the body of knowledge, so the hole specified by (B) is unacceptable.

Here, what exactly goes in (B) must be clarified. Traditionally, in research that produces artifacts, the artifacts leave the researchers’ hands to be evaluated by society. As a result, the structure and function of the artifact become public property, but the process of realization is unrecorded and lost. Recall the first distinction. In Type 1 research, the process is formulated and shared by almost all researchers, and although there is originality in the novelty of the selected knowledge, there is no particular originality in the selection method itself. In Type 2 research, however, the selection method is far more varied with no standard, hence originality is required. Originality of the selection method is an important factor of research, because without it there will be no uniqueness of knowledge necessary to realize the original artifact. Nevertheless, there is no way to record the efforts spent in individual research. As a result, Type 2 researchers are not justly evaluated and remain unrewarded. This means the researchers’ efforts fail to become public property in society, and this constitutes a major loss to society when so much intellectual work is conducted in order to produce artifacts in enormous quantities. The elimination of this situation or the recording and systematization of knowledge selection is one way of supplementing (B).

Activity / Reception	Knowledge of a single discipline	Knowledge of an unlimited discipline
Effect on academia (body of knowledge)	Type 1 Basic Research	(B)
Effect on society (real value)	(A)	Type 2 Basic Research

There is another issue for (B). When knowledge is selected from multiple disciplines as mentioned above, steps to integrate knowledge are taken. There is no standard integration method, so originality is required in individual research. Integrated knowledge can be called “a temporary discipline”, and only when this is established, can the researcher become capable of rational thought for artifact realization. In general, the forming of this temporary discipline is a creative activity, however, it is often unrecorded and disappears. It may be named and recorded only when the artifact wins social acknowledgement from the market, but this is an exception. Heat engine engineering, automobile engineering, and aircraft engineering are relatively mature disciplines, but most disciplines have a lower level of maturity where knowledge is simply arranged linearly. Furthermore, there is nothing recorded for new artifacts in new fields. The problem is that temporary disciplines of engineering lack universality, and they not only cannot be applied to other disciplines, but their creation process is not indicated. The task necessary now is to record the original creation of the temporary disciplines of individual research while learning from past experiences of such creations, and then to seek a universal method. This is the issue of (B).

Only when these issues are resolved can Type 2 Basic Research be called true basic research. This new journal, a collection of original papers of Type 2 Basic Research, attempts to resolve the issue.

4 Original paper of Type 2 Basic Research — Characteristic of the journal

Although it has not been pointed out clearly so far, decision of the knowledge selection method, the selection of

knowledge, decision of the method of using the knowledge, the integration of knowledge from different disciplines, and the creation of temporary disciplines are all synthetic actions, and if divided into broader classifications of logic such as deduction or induction, it is hypothesis formation or a process of logical abduction[Term 1)]. In other words, there is no guarantee for the uniqueness of the results. This is an essential quality of synthesis or "making something". There is neither a guarantee for the validity of the synthesized artifacts, nor optimality. In general, a guarantee is granted by a process different from synthesis. For example, the derivation of a principle in theoretical research is synthesis, but its validity is verified by deductive analysis of its consistency with existing theory and by induction through experiments. For artifacts, this is verified by actual use in society. From this perspective, Type 1 Basic Research is totally different from Type 2 Basic Research. Considering the logical structures of Types 1 and 2 research, they both include abduction, but the importance of abduction is greater for Type 2 research through all stages of the research process. Furthermore, in Type 1 Basic Research, the verification process is done by researchers themselves or by other researchers in the same discipline, but in Type 2 Basic Research, it is demonstrated in society, which is unrelated to the world in which research is conducted.

There is uncertainty in whether processes including abduction will succeed or not, and since this is where originality is called into question, differences in verification demonstrate differences in the evaluation of originality. In Type 1 Basic Research, the originality of knowledge newly acquired as a research result is measured by the scale of contribution it makes to the existing body of knowledge, and the processes in reaching the transient hypothetical stage fades into the background and is not evaluated. In Type 2 Basic Research, the research result is evaluated after it is realized as a product by industry and is used by society, but this takes time, and there is no evaluation at the time the research result is obtained. Therefore, a different evaluation method or the "validity of abduction[3]" must be used. Points to be evaluated include the concept of societal contribution, the decision of knowledge selection method, the selection process and result, and the creation of a temporary discipline; these are all part of the abduction process. The original papers of Type 2 Basic Research submitted to this journal record these in detail, and the knowledge contained within will become public property and be evaluated at the same time. This evaluation is that of the validity of abduction, and the mission of the journal is to formulate it.

Even in Type 1 Basic Research, the same problem arises as the importance of advice to society is recognized. Selection of background knowledge, when it was decided that advice was necessary, and application of knowledge from the discipline are abductions that determine the originality of the advice. Since a final evaluation depends on use of advice by society, the evaluation of the validity of the abduction process is sought at the moment advice is given.

The papers submitted to the first issue are original papers diligently written by researchers based on a certain agreement on what is Type 2 Basic Research reached after numerous discussions on the topics mentioned herein, while taking into consideration the history of the institute and its undertaking of Full Research since 2001. The authors communicated interactively with the first-appointed referees of the journal, and the concept of an original paper of Type 2 Basic Research evolved. Now, the journal is finally being published. Although there is no standard definition of what exactly constitutes Type 2 Basic Research as mentioned in the previous section, please note that a common method is used. The validity of a set societal contribution is stated, scenarios for its realization are portrayed, the knowledge selection method for executing the scenario is proposed, and though not explicit, the temporary discipline in which the selected knowledge will be used is created. Some Type 1 Basic Research is also conducted in the created temporary discipline. Here, there are four synthetic procedures as mentioned previously, so there is quadruple abduction. Their statements, portrayals, proposal, and creation methods and contents vary by paper, but these are distinctly different from traditional expressions such as formation, skills, customs, and formalities, clearly expressing the logical structure of the research procedures.

Terminology

Term 1: abduction: (Logic) A syllogism or form of argument in which a hypothesis is accepted that, if true, would best explain the relevant evidence.

References

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