FUNDAMENTAL IDEA OF CYBERNETICS

THE IDEA OF PURE CYBERNETICS AND OF CYBERNETIC SCIENCES

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Cybernetics is one of the most important thoughts in modern sciences but there are many confusions and misunderstandings concerning its interpretation. In this report the idea of "pure cybernetics" is proposed and for this purpose the idea of *information* is at first defined without personification or relying upon our consciousness as a kind of physical action, that is, as the pattern having *parametric* action realizing potential or latent possibility. Information transfer is the transmission of such a pattern. The system having parametric interaction and feedback of information is called *cybernetic*. Cybernetics is a science studying the "system behaviour" of such a system or designing and manufacturing the "cybernetic system" on trial from pure scientific interest. This is the definition of "pure cybernetics", which is a kind of philosophy in etymological sense and is akin to mathematics. However, there is a difference and cybernetics chiefly aims to study the physical system or circuit model considered above. The history of cybernetics is much younger than that of mathematics because of the dependence on modern technology. Nevertheless, cybernetics and mathematics are very important *operation*, warming up our scientific mind or mental activity. The new type of modern sciences, which are warmed up cybernetically may be called "cybernetic sciences". Such sciences in the field of natural sciences is at first considered. Then the influence of cybernetics on social sciences, the law of thinking or the theory of recognition is discussed.

Although the influence of cybernetics as an operation may be observed in many fields of researches, it does not aim to find a so-called "general principle" common to many fields of researches. It is stressed that cybernetics is not a new type of "social dynamics" or technological consideration of physiology etc.

The contents of this report are

I. *Introduction*

In every age there are thoughts associated with contemporary science or technology. For instance, we can find the mechanistic view-point in the 19th century. Cybernetics of today

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may in some respect be an extension of such a view-point but in reality has quite a different nature in its way of thinking. In this report the fundamental thought of cybernetics will be discussed and the trial of how to define it correctly will be the aim.

Cybernetics was at first introduced into Japan from the U.S.A. by those, who were interested in its technological or physiological side or in its side that had bearings on the modern management science. Cybernetics originally envelopes sciences in a very wide scope. Sciences in Japan, however, have been under the influence of strong sectionalism (see IX). This is one of the reason why cybernetics has not been able to develope as an important modern thought in this country.

Recently cybernetics as a thought has been introduced[1] from the USSR by some thinkers. Also in this case I am afraid of a tendency of being introduced too simply. Is the idea of Soviet thinkers introduced merely as themselves and are the social and technological bases of cybernetics in the USSR and also in Japan not sufficiently taken into account? If so, some confusion or misunderstanding may be generated.

Japan is one of the most industrialized countries and automation is now in progress. Japanese enterprises are largely influenced by American management thought, which may, in their fundamental aspect, be said "cybernetic". The social condition in Japan, on the other hand, is different from that of America as well as that of the USSR. It is in some respect *precybernetic*, so to speak, as will be described later (see IX), and still it is highly cybernetic, because of her higher industrialization. By such social condition our fundamental thought, system of education, economic policy, management etc may deeply be modified. Nevertheless, they are mostly still old. Our contemporary social thought seems more or less to be in confusion because of rapid progress of the social condition. In this respect discussion concerning cybernetics may play a very important role in solving such a confusion. There are further many confusions and misunderstandings concerning cybernetics itself and these uncertainties make the social thought more confused.

I myself am one of the biophysicists working in the field of biocybernetics.[2] However, I have been interested in such problems as I occupy a position in the Faculty of Social Sciences in this University. Unfortunately I am now confined in the research of my own field of biocybernetics and not able to go further into such interesting problems. So that I intend in this report to make clear the nature of cybernetics from my own point of view, which was reported in Japanese in a preliminary form.[3] I am of the opinion that simple imitation or review of foreign thoughts, which are only the *upperstructure*, may not develope a new original thought on our own *social ground*. Moreover, it seems to me that there are some ambiguity[1] concerning the fundamental concept of foreign thinkers too. If we cannot have a clear-cut idea on its nature and overcome the various confusions, any trial would be fruitless.

Cybernetics is not merely an idea which came to some thinkers, like Wiener[4] for instance, but one that is generated in modern society having highly developed technology and industry. The technological nature of cybernetics, however, has been told by many authors. So that some important things will be described in II, which are necessary to understand the description of III concerning *pure cybernetics* and those of IV and so forth concerning the *cybernetic sciences*.

Cybernetics is not a science of the so-called intermediate field (Grenzgebiet) as lying on the boundary of many sciences, which is being said as such by many authors.[5] What is

then the *own field* of cybernetics or its object to be studied? In this respect ambiguity is felt in many descriptions. The idea of "pure cybernetics"[8] may clarify such an ambiguity (see III). This is the most important point to be discussed in this report.

According to this author cybernetics is an "operation" which warms our mental activity. If we are possible to be warmed up cybernetically we may have a wider scope than ever, for instance on nature. In IV such sciences of the new age having a broader sight are called *cybernetic*. The social sciences also must have a new way of thinking, which may be called cybernetic too (see IV). In this respect the author stresses that cybernetics is only an operation and, nevertheless, is useful just as mathematics is. Cybernetics can by no means be such a thing like a "dynamical theory of social events". Such a dynamics must be studied by social scientists themselves but not by cybernetists. This can also be said concerning mathematics, which is an useful operation too. The reasoning power of social scientists may be made powerful by these operations.

These two branches of sciences, mathematics and cybernetics, must have pure relation like Platonic love and related to many fields of sciences. It is not necessary to have a new science which may have a polygami-like relation with many fields of researches. Every field must be studied by their corresponding branch of science such as social matters by social science separately in a monogami-like way.

Cybernetics may also warm up the reasoning power of philosophers and in this way it will influence the theory of recognition or methodology. These matters will be discussed in VI, VII and VIII.

Social bases of cybernetics will be discussed in IX.

II. *Technological Foundation of Cybernetics*

One of the most important idea of cybernetics is that of *information*, which is quite a strange conception in natural sciences. In modern technology, however, it is now one of the most important object to be studied and the possibility of its mechanistic or materialistic interpretation is now suggested. This is why many thinkers, especially those in the field of philosophy, are driven into confusion. In this report this strange idea is tried to be confirmed on physical bases, excluding the *personification*.

As this idea is originally the technological one, the development of modern technology will be at first reviewed in short.

(1) MECHANISM OF OLD AND NEW TYPE

The old mechanism is a combination of parts or machine elements and the combination is *flexible* in contrast to the *solid attachment* of parts as in the case of "instrument". These parts or elements are under the action and the reaction of mechanical forces, i.e. they move under the influence of direct action and reaction in the sense of Newtonian mechanics.

The appearance of such mechanisms was very important in the history of technology as well as of economy (see Note). In some cases the development of productivity may be limited by human being when it is working on the production lines. In a certain stage of history even the masterhand suppressed the explosive development. The mechanism which appeared in the 19th century expelled such a masterhand or skill of the occupants, in simplifying the mode of power application as well as the processes.

Note The definition of machine given by Marx is very important but some complements from the view-point of mechanics may be wanted. In the case of instrument parts are attached *firmly* to each other and their complicated relative motion cannot be expected. So that skill is required of the occupants. On the contrary the parts of machine can make a complicated and useful relative motion, because they are combined flexibly and not attached to each other firmly. From mechanics the relative motion is very important to understand the character of the machine. Due to the mechanism the power, which is applied to a certain part, can be transmitted to other parts through the mechanism. Thus the simplification of power application enables to expell the skill of occupants.

From the view-point of modern technology skill is a kind of *information processing*. In the age of manufacture man relied upon the training of human sense organ and of the muscle control instead of automatic measurement and control in the sense of modern technology. So that we can say that skill which was once expelled is mechanized and automatized today.

This is one of the technological aspect of automation.

In the mechanism of today, on the other hand, the indirect interaction is highly used. For instance, the system A of Fig. 1 sends signal to B instead of direct action of force. According to this signal the system B amplifies it or makes some power modulation (for instance PI or PID action of automatic control) and induces the action to B corresponding to the signal autonomously. The energy necessary to this action is supplied by another one, B′, and A is independent of the direct action to B. Such a correlation may be called the *informational* one and the indirect action is called *parametric forcing*.[3]

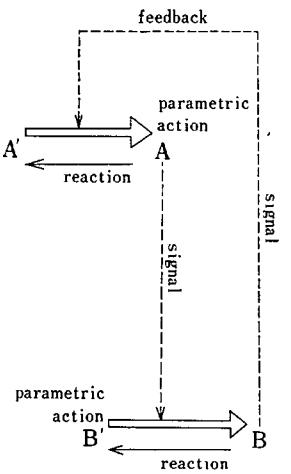


FIG. 1. FEEDBACK

If B reacts to A indirectly, i.e. B sends only a signal corresponding to this reaction and the direct action A′→A is controlled by this signal from B, then such a type of reaction is called *feedback*.

In the parametric forcing energy and material, which are necessary for producing the response, are already prepared in *potential* or *latent* form and only triggered by the signal. In Geiger counter, for instance, electric high potential is applied and in the Wilson's cloud chamber supersaturated vapour is prepared. Therefore, the response is energetically and materially independent of the signal input, which controls only the rate of realization of this potential possibility.

Energy is also necessary to transmit the signal. Even the parametric action of this signal requires a certain amount of energy too, although it is in general very *weak* compared with the one necessary for the response, i.e. such a kind of energy is different in principle from that necessary for the response. The latter is in general *larger* than the former. The mode of mobilization of energy of this kind is sometimes called amplification or power modulation. The energy of activation also is the energy of this kind, which controls parametrically the rate of quasi-chemical reactions.

So-called "objectivism" may be a tendency of neglecting the effort corresponding to the energy of activation or the energy necessary to the information transmission or to the

parametric action of the signal. The potential possibility of our social life also cannot be realized in its natural course but can be first realized parametrically by our subjective or initiative efforts.

In physics or chemistry the potential possibility may be clamped catalytically or thermodynamically frozen. This is why such possibility cannot necessarily be realized. Its realization corresponds to the appearance of response and the parametric action to its triggering. In the case of chemical reaction the existence or the non-existence of the corresponding catalyzer is the "binary digital" information and the flux of reaction corresponds to the "response".

In many physical phenomena, especially in mechanics, the possibility turns to its realization at once and physicists were accustomed with such a way of thinking. However, in chemistry there are many reaction systems which are thermodynamically possible but frozen because of the lack of suitable catalyzer. In the reactions of the living organisms catalyzers like enzyme play very important role.

Also in the field of physics we can see the phenomena like supercooling, supersaturation etc., which were called "Überschreitung" by Volmer.[6] Physicists, however, were unfortunately not accustomed enough, in many cases, with such a consideration and we confined ourselves to the idea of direct action of force or *intensive factor*,[7] which brings us somewhat deterministically mechanistic view-point.

In the history of technology the device of parametric action or the mechanism of information and control appeared in "scoggan" made by a boy, Potter, as a control device of the Newcomen engine as well as the governer, which had already been used at mills and revised by Watt to equip the steam engine. Formerly such devices or inventions, however, were not those making the main current of technology. The main current was the refinement of the mechanism depending only upon the *direct* action and reaction of mechanical forces.

(2) FREEDOM OF INFORMATION PROCESSING

The new mechanism of parametric interaction has the freedom of information processing. The mechanism of the old type is in many cases still used as the base structure, over which the upperstructure of information and control can be efficiently constructed.

In a control system the self-regulation is very important, because the information and control may be easier, if the selfregulation can function highly. In such regulation the recovering forces are directly produced, if an unfavorable deviation appears. Such a direct action of force is called the *intensive factor*. In many cases the effect of the intensive factor, i.e. its response, can be expressed by

$$\text{response (or flux)} = \text{throttling factor} \times \text{intensive factor} \tag{2.1}$$

Now, in parametric action the throttling factor plays a role. So that there is some freedom of information processing, if we take the mechanism of information and control into account. On the contrary, the self-regulation system may be a kind of built-in stabilizer, depending on the intensive factor alone.

"Deterministic view-point" of the mechanistic theory might be due to the situation that the scientists of the last century were too much accustomed to such mechanisms or correlations without any freedom of information processing.

In the case of feedback device the direct action of B to A etc. is tried to be eliminated, so that only parametric action of B to A etc. may be realized by information transmission and power modulation. In some cases the transmission of both the parametric and the direct

action like the three-legged game is possible. In the living organisms the combination of the two types of correlation can be expected to be observed.

In this report the system of informational correlation, i.e. the system having feed forward and feedback of parametric action, is called the *cybernetic system*,[3] which may exhibit some interesting dynamical characteristics from the cybernetic point of view, if it is well designed. Such a designing or manufacturing is the aim of pure cybernetics of III.

III. *Idea of Pure Cybernetics*

To what field of science cybernetics belongs has been disputed by many thinkers. There is an opinion[5] that a certain problem which is *common* to many fields concerning information and control is the object of study in cybernetics. If so, cybernetics can only handle the second-hand problems which have been already studied in their *own* fields.

Considering this an idea at first came to this author that cybernetics may be the automaton theory. If so, automatic control, which is a typical example of automatic machines must be excluded, because the mode of its action is ordinarily *analogue* or continuous except the case of on-off or digital control.

The second idea, which came to this author is that of *cybernetic system* considered in II and he considered the following definition, i.e. cybernetics is a philosophy in etymological sense considering the mathematics of the cybernetic system, which can be digital as well as analogue, and designs and manufactures such systems on trial from the purely scientific interest.[3]

There is a field which may be called cybernetic technology but the pure cybernetics does not aim at such a practice, because the designing and manufacturing is from purely scientific interest. That is, what is then the system behaviour of such a feedback system of human work? This is not a matter of engineering or technology but of a pure science.

Pure cybernetics might be considered as a kind of mathematics, if Turing's idea of designing the calculating machine is taken into consideration. This author, however, is of the opinion that there is a difference between mathematics and cybernetics, because the principal aim of the former is to construct a logical system inside our mind and the manufacturing of the Turing machine is only a trial or a subsidiary means of mathematics, while the latter aims exclusively to design and manufacture the physical system having the cybernetic function or system behaviour.

Mathematics has a long history but cybernetics does not. This difference may be due to the level of development of technology. In the old time of Babbage we can already see the embryo of the cybernetic system or of modern thought but it was not able to develope, because the technological foundation of that era, which was manifested by Jacquard machine, was not yet matured enough to cultivate Babbage's idea. Recent development of electronics, circuit theory, servo-mechanism and other modern technology made this old idea possible. Moreover, we have knowledge concerning the feedback system of living things. These are the reason that besides mathematics, cybernetics have at last come forward. This may be very important in considering the education of mathematics.

At least, the practice using relay circuit is required to be taught in high school and in the general education at Universities. Students in every field must be accustomed to the

cybernetic system just like mathematics. It is reported that in the USSR high school students are trained in this direction. Cybernetics may for the time being be a part of the mathematical course, stressing set theory, Boolean algebra, computation using binary numbers, theory of probability and information theory and so on combined with the practice of relay circuit. In the future, however, it must besides mathematics be an important course in education, where automaton theory as well as the theory of feedback system or of automatic control must be taught. Every student must be warmed up by such a training.

Is cybernetics, then, a branch of physics or any other natural sciences? Cybernetic system is a kind of physical nature and the process cannot be realized against the law of nature, for instance the law of thermodynamics. However, they do not proceed in the manner like wild animal but are controlled like tamed animal. In the case of electronic analogue computer DC amplifier is used for this purpose of taming (see Fig. 2). Physics is the science of phusis (nature), which is not artificial. Cybernetic system, then is not the phusis in the ancient Greek sense but an artificial one made by human hand.

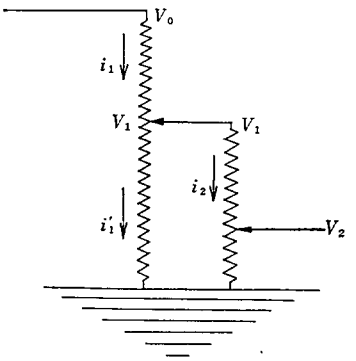


FIG. 2a.
SIMPLE POTENTIOMETER

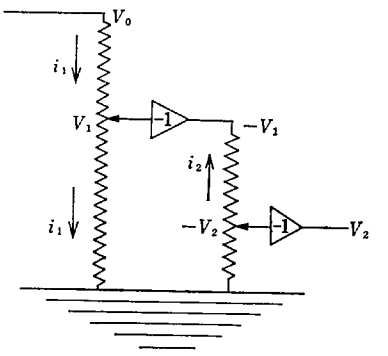
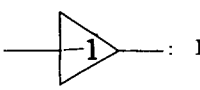


FIG. 2b.
POTENTIOMETER HAVING DC AMPLIFIER



: DC amplifier used as a sign changer

In Fig. 2a there is potential drop in V_1, because of the branching of the current, $i_1=i_1'+i_2$. Thus the mathematical exactitude is disturbed. In Fig. 2b there is only the correlation through the signal between V_1 and $-V_1$ or $-V_2$ and V_2. Thus the current i_1 and i_2 are quite different. This elaborate system is like a tamed animal.

The law of nature provides us with the potential or latent possibility, which may be clamped or frozen in its potential form and its realization is controlled parametrically by information. In the living things such a control is realized enzymatically. This, nevertheless, is a matter of biology and not of cybernetics. Cybernetics is a trial to design and manufacture such an artificial system of scientific interest. Therefore, it is neither a branch of physics nor of biology.

Cybernetics is not a special science studying the law in the corresponding special field, like physics, biology, psychology or social sciences. However, we can take the cybernetic view-point into consideration, which is very important in every field of science and warms up each scientist mentally. The new type of modern science thus warmed up will be considered

in IV and so forth.

In Western thought, knowledge is power (F. Bacon). In the case of cybernetics this power is manifested by the operation of warming up. What is then the meaning of considering pure cybernetics? Such a purification may correspond to a kind of *round about production*, which may be the antithesis of the final aim like negative film in photography. If we look at such an antithesis, we can find the phrase "philosophy". If we, on the contrary, look at the positive one, then we can find the phrase "knowledge is power". Therefore, philosophy in etymological sense may correspond to the round about production seeking greater power in knowledge. On this point there seems to be a difference between Western philosophy and the attitude of the old Japanese mathematicians in the Tokugawa age, who denied the utility of their knowledge.

IV. *Cybernetic Sciences*

If we call the new type of sciences suggested in III cybernetic sciences, then we must meet the problem of whether it is possible to consider such ones or to use such an adjective "cybernetic". Meanwhile, there is the term mathematical physics, which is used in stressing the recognition of the mathematical aspect of the physical world, so that let us consider at first the case of physics.

(1) CYBERNETIC PHYSICS

The law of physics corresponds to the behaviour of the physical world and is not a simple logical construction. In natural science it is generally forbidden to look at world through a coloured mental glass, which is somewhat *subjective*. If so, the adjective "cybernetic" seems to be useless.

However, we must use an *adequate* filter to take a more realistic photo. In the same way we must be trained in a language, if we want to understand the words spoken in that language. We must also have some training which is necessary to understand what is spoken by nature. If so, cybernetic training must be a necessary warming up of our scientific mind. In this case we ought not to interpret the spoken content artificially. In this respect our recognition is not subjective but *objective*, although our hearing power depends on the training.

This is very important and an interesting problem from the view-point of the theory of recognition (see VIII).

Then the cybernetic behaviour of the physical world, phusis, can of course by no means be subjective. Although it is objective, it is not possible to perceive it, if we are not warmed up by scientific training. The pure cybernetics considered in III may play a role in such a training of our mind. This is the reason why we are considering cybernetic physics or sciences.

Let us review here the development of modern physics. We can say that it is the history of conquering the mechanistic view-point of the 19th century. For instance we have the field theory of electro-magnetism and the theory of relativity. In the former one mehanistic interpretation of the lines of force and in the latter one the old mechanistic idea of ether were eliminated. Quantum theory of matter and statistical thermodynamics were also the monuments of such victories.

The modern theory of irreversible processes is a very important development of thermodynamics but the throttling factor of (2.1) are ordinarily assumed being constant. Such an assumption is due to a narrow view-point and in this respect this theory is still mechanistic or *deterministic*. The matter cannot be modified, even if the cross term[8] is taken into account in (2.1).

The parametric action considered in II is dependent on the *flexibility* of the throttling factor of (2.1), so that we must consider the non-linear flexibility of this factor, if we take a feedback system into account.

The author of this paper was interested in thermodynamics of transient phenomena[9] or dynamical stability of a flux system, in which the field of chemical potential or the intensive factor along the *reaction coordinate* exists. If the field of the intensive factor vanishes along a certain reaction coordinate, although the total system is not in equilibrium, then such a coordinate is called the *quasi-equilibrium* coordinate. If the field or the intensive factor exists, although the corresponding flux vanishes, such a coordinate is called the *frozen* one. He studied the dynamical behaviour of such a flux system in general.[10] However, he did not yet have the idea[7] of the "flexible throttle". He obtained this idea first about 1958.[11]

From the cybernetic point of view a generalized theory of irreversible thermodynamics may be possible,[12] where the discharging processes of the stress of non-equilibrium are controlled parametrically by information. If such a theory is possible, the deterministic view-point will be expelled and the new idea of "development" may be introduced into physics.

It is well known that the complementarity of quantum theory expelled the deterministic view-point but still it is not so powerful enough in expelling the determinism ultimately. The idea of parametric interaction or informational correlation can expell it from the corner where quantum theory is powerless.

Molecular system requires in reality infinitely large number of variables to express its physical state. In thermodynamical equilibrium, however, the number of such variables becomes fortunately very small. In the phenomenological theory the number of variables is still finite because of the coarse graining. In cybernetics we must ordinarily take a *finite* system into consideration, because we cannot in practice go well with infinite system. This is the important difference of cybernetics from mathematics. In mathematical consideration we can take infinite system into account relying upon the idea of limit and mathematical induction.

From cybernetic point of view the equation of kinetics of irreversible rate processes can be simulated by the circuit model like that of an analogue computer, if the number of variables of kinetic equations is "finite". This number may be made finite by grouping the variables as in the case of mathematical economics or coarse graining.

In this occasion let us consider the definition of "compartment", which is the region in the functional space where chemical potential of a certain component has the same value as well as the same functional form. The mean value of particle numbers, n, in this region corresponding to a value of chemical potential, μ, may be given by

$$\bar{n}=\frac{\partial(pV)}{\partial\mu}\,, \tag{3.1}$$

when p is pressure and V is volume. We will not enter into the problem of whether we can define grand partition function or not in a strongly dynamical and irreversible system like the living one.

From the view-point of molecular kinetics the metabolic system of organism may also be

expressed by such a system of differential equations.[2] In this case however, the situation is very complicated, so that the number of simultaneous equations should be tremendously large and in many cases they are strongly non-linear, especially in the case of repression or induction of enzyme formation of *E coli*. Cybernetics want to simulate such a complicated system using a finite model. If such a simple and finite model is not applicable, cybernetic consideration may be powerless. For the purpose of simulation, therefore, an adequate simplification is necessary.

Here, let us differentiate the two types of model.[13] The one is *direct analogue* model, like the fluid model using tank and valve system. Another one is the more abstract one like the analogue computer programmed so as to simulate the system which is expressed by simultaneous differential equations. This type of model is called an *indirect analogue* one. In cybernetics the latter is mainly considered, because the indirect or parametric interaction is highly utilized in this type of model, instead of the direct or intensive one, which is the case of former model. In some cases the computer simulation using general purpose digital computer is possible too.

(2) CYBERNETIC BIOLOGY

Physiology is one of the most important homeland of cybernetics. Physiology, however, is a science basing on the physiological experiment, so that it seems to be of no use to introduce a technological idea to reform the theory of physiology. There is, nevertheless, cybernetic feature too. Living organism is composed of molecules or of molecular system like membrane, granule etc. Therefore, they cannot behave against the law of physics and chemistry. However, these possibilities are not necessarily realized but frequently maintained enzymatically in a potential form. The rate of realization, i.e. flux of the rate process, is controled parametrically by the "products" of other rate processes, for instance hormone. So that there are parametric interactions or informational correlations[12] between these rate processes in vivo and these correlations may in some cases make a logical circuit, which is called molecular automaton[14] in the case of *primitive control* system. This is a kind of natural automatic computer and at the same time rate processes in vivo themselves are under the computer control just as in the case of automatic chemical plant. Thererfore, cybernetics warms up our mind which can perceive the function of the living things.

The relation of cybernetics and neuro-physiology has already been discussed by many authors, so that another aspect of biocybernetics will be discussed here.

There are abrupt change in organism like differentiation[2] of cells, metamorphosis and so on and in such changes the old model of the metabolic system must be *switched* into another one. Let us consider, for instance, the metabolism of a silk worm. It can be represented by a model in which some factors can be neglected for purpose of simplification, if they are not important in the metabolic system of the worm. At the critical stage from worm to pupa, however, some of the factors neglected may become very important and we must take another simplified model into account corresponding to the pupa.

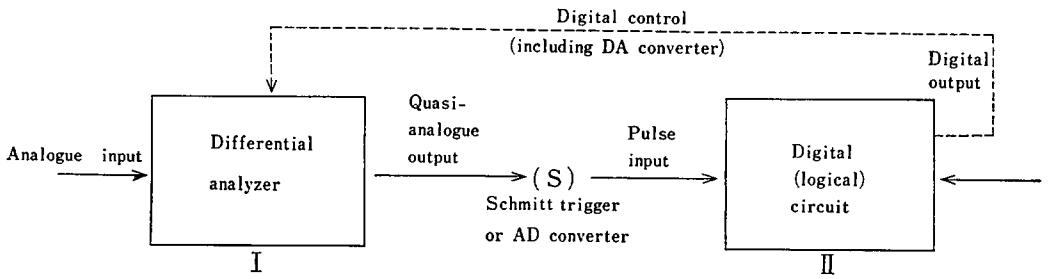
In the transient state of metamorphosis, however, another kinetic system must be considered too.

If we are able to handle the problem of the system of infinitely large number of simultaneous non-linear equations, we might have an unified mathematical theory including that of the larva, as well as of the transient state and of the pupa. However, it is well known that

"the phenomena are more complicated than the essence (Hegel)". This is also true in our case. To get such essential features we have to simplify the matter neglecting some of the factors which are not important. The kinetics of such simplified system may be represented by an analogue computer having a certain programming.[13]

In the critical stage the output of the computer is so planned that it emits a signal by using Schmitt trigger. Then the signal is introduced into the relay circuit which is combined with the analogue computer. The block diagram of this computer is switched into another one by the relay circuit.[2),3)]

The combined or hybrid system is represented by Fig. 3.



I: Analogue computer or digital computer programmed as a differential analyzer.
II: Logical (or switching) circuit or a general purpose digital computer.

FIG. 3. HYBRID SYSTEM

Such a model may also be useful in the mathematical theory of economics and other social sciences (see V). In general we may use a differential analyzer, which is either analogue or digital, and hybridized with digital system, i.e. digital computer if available.

In this way the "idea of development" can be taken into account, basing on a mathematical theory. If we stress such an idea only in phrase, like dialectics for instance, it can by no means be scientific but only literary.

If we take only the digital signal into account, then the analogue part of the differential analyzer and the Schmitt trigger or AD converter may play a role of *delay unit*.[2] Then the digital part corresponds to a switching circuit with delay. If we use such a model to represent the primitive control system, then the idea of molecular automaton[14] can be obtained. If we consider this in this manner, we may not have been the subject of criticism by Goodwin.[15] In the switching circuit model proposed by this author,[13),14)] there was not then such a consideration, as Goodwin criticized.

Strictly speaking, the idea of "development" may be the antithesis of the cybernetic consideration, because originally it confines itself with a finite system, in which the development is out of the question. In this respect cybernetics is originally the same as the mechanistic theory of the 19th century. The only difference is the acceptance of the idea of parametric interaction and informational correlation.

Nevertheless, we can pacify the idea of development with the cybernetic consideration using, for instance, a hybrid system of analogue and digital computers. In other words we can spring to a new view-point, which may be called super-cybernetics so to speak.

In cybernetics we must give certain restrictions because of the finite system. Such restrictions may be a necessary bending for the theory to spring over the barrier of antithesis.

(3) ORIGIN OF LIFE

This author regrets to say that he has not the space and the time at this opportunity to discuss this interesting matter. Formerly he suggested[16] an idea that the origin of life may be the origin of the logical circuit composed of chemical system, in which parametric interaction can be found. This idea is still maintained in his mind as yet. The chemical system of ancient time might have the potential in the development of matter before the origin of life as Oparin[17] has stressed, because the mixture of infinitely many components and of heterogeneity (like the surface of coacervate) may provide the possibilities of complicated parametric interactions. It will be very interesting to make a logical circuit experimentally using purely chemical system without molecular regularity in space.

The most important thing to be discussed in this report is that the barrier between the inanimate and the living world is now going to be overcome also theoretically or that we can consider life as a development of physical and chemical phenomena. Such a theoretical development may also play an important role.

This is very important for considering the relation of cybernetics with the theory of recognition (see VIII).

V. *Cybernetics and Social Sciences*

Our society may in some respect be a mechanism and indeed the mechanism of the largest scale which has ever been made by human hand. The fundamental difference from that of purely physical nature is the autonomy of its component, human being.

Cybernetics can originally include such an autonomous being like steerman (κυβερνήτης) in its system. Navigation indeed is not a natural phenomenon only depending on wind and stream but a part of the social events. Of course this autonomy is restricted but even the autonomy of a president or a premier may also be restricted when he is sailing the ocean of "history". There are always the autonomy as well as the restriction in our life and we cannot limitlessly rely upon such an idea, autonomy, if we want to study the social mechanism scientifically.

Cybernetics as itself cannot be a dynamical theory of social phenomena, as was told in I. Such a dynamical theory must belong to the proper field of social science. Cybernetics should not have a polygami-like relation with other field of sciences. It can only warm up our mental activity and provide a new scientific point of view. Whether such a view-point is correct or not must be decided by the study of social science itself. Cybernetics cannot have any power to decide such a thing but has only the good will to suggest. This is also true to mathematics as well as to philosophy. Social science cannot be ruled by the so-called "general principles" obtained outside of the social study.

From cybernetic point of view human being may be a kind of information processing apparatus,[9] although its software is very specific. Fig. 4 is my own mental picture. A part of our memory like feeling or impression of the past may influence the programming of our mental tape. Another part of our memory stored in the cortex, however, has the form of abstract conception or notation and it is highly used for the information processing, just like the case

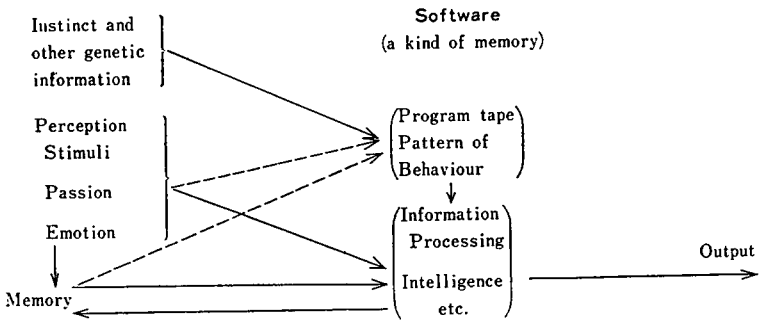


FIG. 4a. ORDINARY ANIMAL

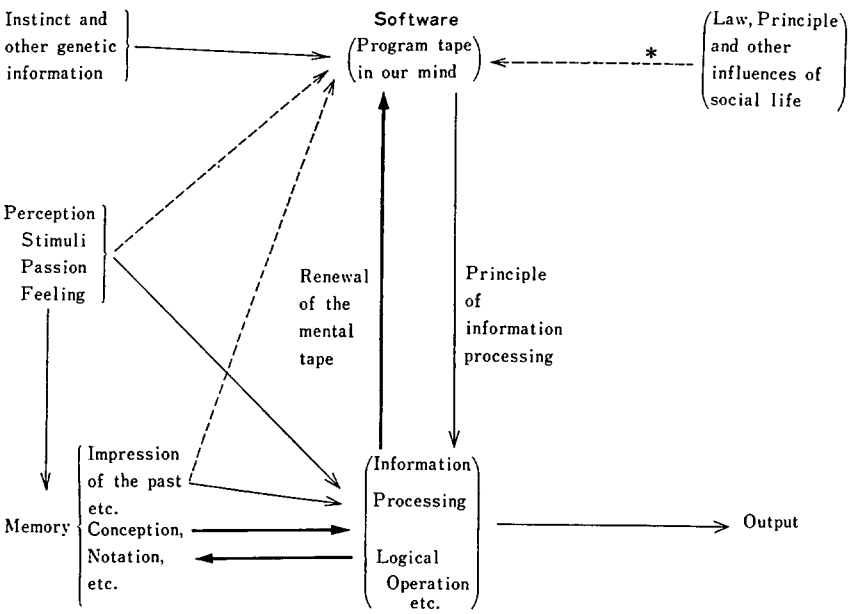
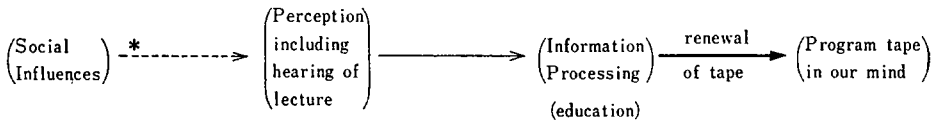


FIG. 4b. HUMAN BEING

This diagram is but a simple illustration. The real pathways, ----→, may somewhat be different. For instance, the part * of the social influence may be of the indirect, round about type like



of electronic computer. Our mental function of logical processing is called "understanding". Our passion influences the processing which hampers our logical judgement.

The programming of our mental tape, which may be a special kind of memory (see Note), may also be influenced by impression, instinct and other factors of our social life, although our judgement itself must correctly be logical. Therefore, if the program tape is under the influence of prejudice or wrong impression, our judgement cannot be objectively just even in the case of logically *correct* processing.

Note In school education we do not test simple memory but the degree of development of the software, in which simple memory is composed in a pattern of behaviour as the result of learning.

Fig. 4 is only a "suggestion" but such a mental picture may be plausible. Specificity of the human being may be in the programming of the software, which was cultivated in social life, especially by education at home and at school. Such an influence of social life is the general nature of primates, in which apes and monkeys are included too. Other animals are not so deeply influenced by social life. In the case of insects the behaviour is almost perfectly determined by its instinct, like a machine controlled by a program tape. In the case of vertebrate the behaviour is more flexible, because of the developed power of information processing.

Considering this, there is no fundamental *difference* between human being and other animals with respect to the information processing or we can say that from cybernetic point of view the difference is only a *matter of degree* of complexity, that is, the ability of information processing is, on the one hand, exceedingly large because of the use of *abstract conception* and, on the other, the program tape is *flexible*. However, the quantitative difference induces a qualitative one, i.e. our programming may change as the social condition changes. The social change, further, is induced autonomously by human work. Such a flexibility makes the fundamental difference of human being from other animals including apes and monkeys. Nevertheless, the human being cannot generally adapt to the change of situation so rapidly, that there is a certain time lag or delay in the modification on its software.

Therefore, there are two sides to be studied. One is the matter concerning the modification of our mental tape, and the other is the study of the social behaviour which can be understood neglecting such a modification.

(1) PHYSIOLOGY OF SOCIAL BEHAVIOUR

If we neglect the modification of our programming, human being can be considered as a kind of information processing apparatus and our society may be a system of groups of such an apparatus connected with each other by communication. The so-called man-machine system may be an example.

In his official life a man is programmed by the principle of that office, although he may be an artist in his private life. It is well known that our economic life has the largest influence on our mental "tape", which is stereotyped in a certain way. Therefore, the dynamical model of modern economics[18] may be reasonable in some respect. From cybernetic point of view, the economic parameters in the theoretical equations may be modified under the influence of economic condition. So that the simulation using the block diagram of Fig. 3 may also be useful in the mathematical analysis of economics. Then, the switching of the economic model may correspond to a metamorphosis in the limit of capitalism or, in a extreme

case, a revolution from capitalistic to socialistic economy. In the latter case, however, it seems to be an oversimplification. We will refer to this later.

Law is also a matter of mental programming. It may be possible to construct a simulator of our legal life using some kind of logical circuit equivalent. There is some careless or intentional acts blocking the law and the corresponding penal code. For this purpose of simulation we may use the hybrid system of Fig. 3 too, where the analogue part corresponds to the restoring action for the illegality. In the railway diagram expert tries to get the restoring function when the regular diagram is disturbed. We, in the same way, can get the sight over the behaviour of the legal system using such simulator. Cybernetics does not want to go further into details but may provide a "teaching machine" in cooperating with jurist, if such a machine is wanted in the field of jurisprudence.

From cybernetic view-point a general purpose logical computer may be useful for this purpose, which makes logical operation like AND, OR, NOT etc. instead of numerical computation. The storage of this computer may store the data of only "one bit" instead of numerical values. Such a special computer is now used at process plants. Perhaps it may be useful in social study.

(2) MODIFICATION OF OUR MENTAL TAPE

Nationality, tradition, custom, various thoughts and others are taped in our software but they are by no means permanent. The most important thing to be noticed is the different pace of the individual modification, which is influenced by personality too. Some of the software are progressive, so to speak, and others conservative. We may write the pattern of our mental tape in the form[3]

$$\text{typical one} + \alpha\,, \tag{4.1}$$

where α represents individual or personal deviation from the typical one of that age and society. The behaviour of each α may be very important in the field of philosophy, psychology, literature, education and others. In social science, however, a mass of the individuals having nearly the same α is important, because the idea of one or two persons can hardly affect the social movement. Then, there are many groups of people having common α and the struggle between these groups may be expected. In this way the natural course of progress or modification of our mental tape is forced by other groups, similar to the old story of "Koran or Sword". Cybernetics will provide technique drawing picture mentally and make social scientists consider the matter easily. (There may be many ways in taking mean value of α).

If the role played by α is buried in the mass, the social behaviour in this condition may be interpreted as the assembly of the typified software. Thus the social model considered in (1) may probably be justified.

In the theory of rate processes the intensive factor, on the one hand, is a certain kind of mean value, i.e. chemical potential is the mean quantity of this kind. On the other, we consider a mean quantity concerning the activated complex of the corresponding rate process. We consider quasi-equilibrium of the activated one and the normal or mean molecules, and the equilibrium constant, which depends on the free energy of activation.[19] The mean value concerning the activated molecules may correspond to a certain group having a special pattern of α. Our society is a heterogeneous one composed of many groups of different α and the mass of each group tries to manifest their power.

Our thought is an abstract one which could hardly take a geometrical figure or form.

Physiologically, however, it may be nothing but a certain pattern of synapsis of our nervous system of brain, just like the program tape of the Jacquard machine, in which a certain figure or design of lace is converted into the punched pattern of the tape and this pattern is also converted parametrically into a lace pattern. Therefore, we may have a mental picture of a certain mental tape of α, the pattern of which affect the social movement parametrically and the pattern itself may also be affected by the social movement (response) as will be described soon after. Such a movement of pattern can also be observed in the case of virus DNA or RNA in a host cell. (The evolution of living things may also be a kind of such a movement of genetic code). The activity of the virus is limited only in a special host. In the same way our mental tape of a certain α, that is a certain thought, may have its social life only in a certain host society. In this way a pattern of thought may be cultivated and developed in that society.

(3) RESTRICTION OF THE MODEL CONSIDERATION

In a mathematical model of living things the aging or deterioration is ordinarily neglected or abstracted. A professor of physiology told me that it is rather difficult to consider why the organisms age and deteriorate. In the same manner, whether the capitalistic economy ages or not is ordinarily abstracted in the computer simulation. However, the simulation is not so simple as in the case of larva.

Recently there are groups of executives of enterprises learning the new management idea. This may be the trial of modification of their mental software considering the metamorphosis of modern society. It is also necessary for working men to change their mental tape looking at this metamorphosis. They are frequently against automation but they are now in a critical stage whether they must purify their software so as to be clear of their consciousness as a proletariat, because their professional ability like skill, knowledge, and experience depreciates and their position as a small proprietor is now in danger.

α may have the pressure on social affairs, if a mass of the same α cooperates. This action, however, is *parametric*. Let us consider an engineer driving a locomotive. He cannot drive it with intensive factor but works at the information processing apparatus parametrically. (see Fig. 5). This is also true in driving the locomotive of our society.

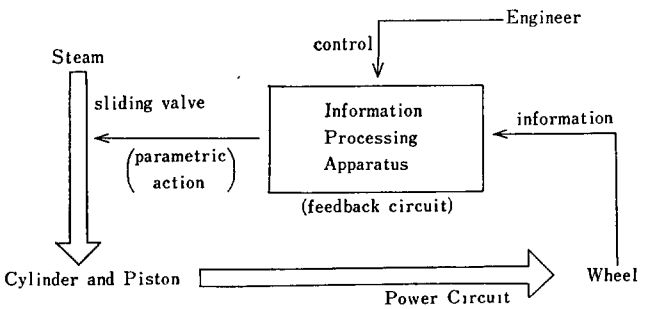


FIG. 5. DRIVERS INTENSION IS CONVERTED INTO LARGE PHYSICAL FORCE

The function of law also is parametric, so that it can be converted into physical action by means of human control. Its restoring action against the illegality may thus be simulated by some kind of physical model, as was suggested in the name of teaching machine of jurisprudence.

Cybernetic thinking shows some times a *weakness*. In the background of parametric action there must be the existence of the intensive factor. If this intensive factor does not exist, then any kind of information processing is useless. If the fire of a locomotive, for instance, goes out, then any trial for parametric action may be only under a spell. In cybernetic consideration, however, such a *background* is abstracted and only the parametric action is discussed (see Note). The background may be a kind of antithesis of cybernetic consideration but, nevertheless, it is in many cases neglected by careless thinkers.

Note Information theory is one of the most remarkable one in modern technology and, nevertheless, somewhat narrow in the way of thinking, that is, in information theory only the complexity of a pattern corresponding to a certain signal is quantitatively estimated and mathematically treated. Energy and material is of course necessary for its transmission but such backgrounds are extracted in considering the entropy of information and the stability of the information to noise is mainly discussed. The utility of this theory comes from such an abstract way of thinking. The attitude of this kind may be the antithesis as was stressed above.

In our society there are many intensive one dynamically driving history. In this case we must have *another training*, which is different from the cybernetic one. If we are not warmed up by such dynamical view-point and only warmed up too *strongly* by cybernetics, we have the danger of falling into *superficial rationalism* unable to percept the "contradictions" or the *under current* of society.

We can drive the locomotive of a large power. In general we can mobilize large energy parametrically. Physical power thus mobilized may react to our social system. However, it does not react *directly* promoting the social progress, because every thing which influences the social system must once be accepted by human brain (Engels). So that we cannot consider the direct interaction of physical system itself with social model or simulator, although the latter looks like as if it were a physical system.

There is a fiction that mankind shall ultimately be ruled by machines. If such machines are phusis, such a fiction is nonsense. If not, the machine must be an extension of the human function, so that the tyrant in future must be those mankind, who are the legal owner of these machines, because machine is a kind of capital goods. So that its social pressure must be the pressure of the capital.

In cybernetic *model consideration* persons are in many cases used as part of the model of the circuit, for instance in the case of war game or business simulation. In ID (Industrial Dynamics) of Forrester[20] also such an experiment is tried. During the experiment they are working as a kind of information processing apparatus and they must judge according to a given rule or principle. Their autonomy is utilized. Therefore, they are used here. However, it is restricted.

What is the restriction of the autonomous power of mankind? Such a matter is out of the scope of cybernetic consideration but cybernetics may warm up many fields and bring the budding of many problems, some of which may even be antithesis of cybernetics.

The only reply to the question about the limit or restriction of human autonomy may, as is well known, be the one given by Engels concerning the definition of freedom.

VI. *Thinking and Consciousness*

Regulation is one of the fundamental function of life. Unicellular microorganism has already such a function of information processing.[13),14)] If we define the *thinking* as the information processing for maintaining life, i.e. for the regulation of the metabolic system or of dynamical biochemical system, then the lower organism also have this function, although its degree is very low. Higher animals have higher function including the processing for the social life of those animal but may perhaps not possess the *consciousness*, which may be the function of the human being alone.

What is then the difference of thinking and consciousness? Thinking may be defined as the *direct* information processing for living. In mankind, on the other hand, there is an *indirect* information processing, in which the direct processing considered above is again processed. Further, such direct and indirect processings are again under the information processing of higher degree. Thus we have the function of self-examination or introspection.

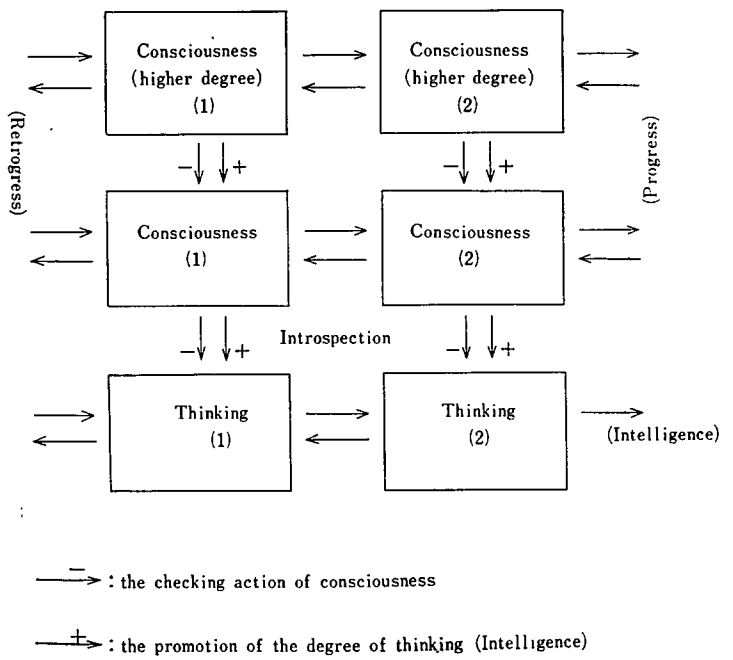


FIG. 6. THINKING, CONSCIOUSNESS, AND INTROSPECTION

This may be because of the higher degree of freedom of our information processing. Mankind will be drown, if he has not the training to swim. On the contrary, even young animals can swim without training, because their degree of freedom of movement is limited. In training we must clamp some freedom and promote some others.

In our mental tape there are many things stereotyped. Some of them are concerned with

old customs, traditions etc. In ancient times totemism might be recorded in their tapes. However, we cannot go well with such an old one. There is, so to speak, a kind of antinomy. If we want to maintain the old tape, then we are against social progress and we can hardly maintain our social life. If we wish, on the contrary, to revise the tape radically, then we shall exeperience a tragic destiny.

Thus we can consider a kind of self movement of personal software, just like the case of social movement of α-tape (see V). If a living cell is infected by a certain bacteriophage, then the pattern of the phage DNA influences the cellular metabolic system and we can see a self movement of its pattern (in this case reproduction of the phage DNA). Almost in the same way our mental tape may develope in a certain autonomous manner. This is why the consciousness is observed only in the human being. It may probably be difficult even for apes to have such a function, because the degree of freedom of their information processing is perhaps not sufficient for this purpose. It is also important to consider the self-development of personal software. (α may be different according to the degree of grouping).

Intelligence of higher animals is also a kind of direct processing of information for living and they may not be conscious of their own intelligence. Therefore, intelligence is not equal to the consciousness itself.

There is a question whether machine can think or not. Machine can simulate the thought process but it is not living, so that it is not necessary for a machine to process information for living. If we call the information processing of computer *thinking* too, then its function may be of the lower degree even than that of microorganism. Therefore, it is out of the question to ask the possibility of machine being *conscious*. Machine is not a living thing, so that it cannot aim or struggle for life and cannot be conscious for living or developing its software autonomously for better and happier life.

As a physicist this author tried to eliminate the "personification" in defining information. This is a very important thing. People, especially those in the field of philosophy, used to consider information as an idea concerning our consciousness. This is a very dangerous tendency and thus may bring forth some confusion. Information is a material pattern working parametrically and for this action and also for the transmission a certain amount of energy is required. Information is nothing but such a physical action. Information processing is also one of the function of living things, which can also be independent of consciousness in many cases. Main part of our physiological as well as social life also is under the unconscious information processing, like those of the autonomous nervous system, of humoral correlation and of conditional or unconditional reflex. The training in our official life aims to obtain useful conditional reflex.

Confucius said that mankind can behave quite naturally and in a refined manner even after 70 years of life of hard training. According to the theory of conditional reflex we some times do not know what we are doing. That is the nature of a reflex. If we are conscious, on the contrary, in such a work, in which we are well trained, then we cannot behave smoothly and in some cases apt to become as a rigidified body. In such a case our consciousness may have a harmful self-checking action (Fig. 6). In some cases, however, it is very important and a useful function, which is the function of human beings alone. In the self-discipline of oriental priests there seems to be a conscious control of suppressing the function of his consciousness. Such a suppression can be shown by the experiment of the brain wave. The signal from every part of our body seems to be blocked at the end branch of the

channel and is not informed to the cortex. So that the top management may be rather easy and the brain wave shows α wave. In case of Western thinkers or priests, on the contrary, the training is mostly that of top management, i.e. informations are transmitted to the cortex and processed by the top, I suppose. Japanese physiologists are of the opinion that there is a difference in the brain wave between the priest of Buddhism and that of a Catholic, so that there is a certain difference in their training.

When we take the development or the self-movement of human software into account, information may first in that stage be combined with our consciousness. The topics here discussed are very important in the original field of philosophy. As I am a physicist I do not want to discuss the matter in detail and would like to leave the matter to philosophers. This is not the proper matter of cybernetics but it may be the matter of super-cybernetics, so to speak. However, pure cybernetics of III may warm up our mind and provide a new point of view. It will also promote the budding of new philosophy.

What is then the limit of such a self-movement? I would also like to leave the matter to the proper field of philosophy. Only the following is suggested, that if we consider that the self-movement of our software is almighty, i.e. limitless, then we must fall into an eccentric idealism. If we, on the other hand, consider that it would exclusively be typified or programmed by our economic life, then we may fall into mechanistic view-point, which is apart from the so-called materialistic interpretation of history.

I am anticipating an interesting field of philosophy to be developed in the not too distant future. This is due to the development of modern sciences, which has clarified the development of life from lifeless physical world and also the evolution of mankind from animals without consciousness. In this manner we can consider our mental activity and consciousness on material ground. This is not the merit of cybernetics alone but cybernetics also play a very important role in this development.

From the theory of recognition our knowledge concerning the material world is modified by our mental function which may likely be *subjective*. This is true but our subjective function at the recognition is nothing but the function of our software. Engels pointed out that this function is a highly developed form of the material motion. According to the vulgarized materialism our thought is secreted by the brain just as the gastric juice is secreted by the stomack. From cybernetic point of view our software also is a special form of material motion, although the detail of the neuro-physiology is not yet clear. Our subjective function at the recognition may be a highly developed form of the self-movement of our software. On this point we cannot be conclusive now but we might fall into subjective idealism, if we deny such an attitude as described above.

VII. *Law of Thinking*

Although logic is an important function of the information processing of human being alone, we in some cases bind ourselves in inconvenient manner by logic. Then, it might be contrary to the function of life. However, our reasoning might be disturbed, if we neglect the logical step, and the situation is like the confusion in accounting.

What is then the tunnel through which we can flee?

(1) CONSIDERATION OF TIME DELAY AND DIFFERENTIAL EQUATION

From cybernetic point of view one of the ways is to introduce time delay in considering logical consistency. For instance, should I have no cash to pay now, there may not be trouble in accounting, if I have the possibility to pay in the next month or am also believed to have such a possibility. There may be some special procedure in accounting, I presume.

In such cases formal logic is powerless, because the belief in the possibility is the *key point* and this cannot be handled in a *formal* way.

Logical circuit system having time delay is called automaton. If we consider a digital system logically, which is dynamical, then it may be simulated by a kind of automaton. On the contrary, the system must be static, if the logical consistency is maintained simultaneously at a certain time. In dynamical system the logical consistency is maintained taking the future into account, so that a movement seeking the logical consistency may be observed.[21]

In continuous system we must use a system of differential equations. In "Industrial Dynamics" a differential equation of the first order like

$$\frac{dx}{dt}=a-b\,, \tag{6.1}$$

is used as a component equation, although Forrester[20] did not use such a notation. If $a=b$, the system is balanced in a steady state (simple reproduction may correspond to such a case). If dx/dt is very small and can be neglected compared with a or b, then we have the case of quasi-equilibrium (comparative statics may correspond to this case). If dx/dt cannot be neglected, the balance $a=b$ may be modified in the form

$$a=\frac{dx}{dt}+b\,. \tag{6.2}$$

This is not an equation of algebra (expanded reproduction may correspond to this case). If an algebraic equation is available, then no movement of any kind can be observed, just like the case of logical circuit without time delay.

Some thinkers, especially those in the field of Marxism, are anxious of cybernetics being *mathematical formalism*. Such an anxiety, however, is unreasonable, if we have only some dynamical sense looking at the logical circuit having time delay or the differential equation like (6.1). What is then the dynamical sense? In equation (6.2) the balance is maintained by anticipating sufficient rate of buffer action expressed by dx/dt. In the d'Alembert principle of mechanics (see Note) the balance of external force and the force of inertia, which is experienced as if a real force when we push a matter and give an acceleration, is considered. Such a *sense* of force is necessary in our mathematical consideration of dynamical systems. Only when such a sense is lacking, the mathematical formalism or the superficial *rationalism* may arise.

Note In this principle the differential equation of dynamics $ma=f$, where acceleration a is the differential coefficient of the second order, is written in the form:

$$f-ma=0,$$

i.e. the form of balance of forces, where $-ma$ is called the force of inertia.

Kinetics of metabolic system can also be expressed[2] by the simultaneous equations like (6.1). If we consider a logical circuit combined with a simulator of such a system of equations, then we can have an automaton including continuous system, in which the analogue part corresponds to the delay unit (see Fig. 3), as was described in the case of molecular automaton.[14] Such a consideration may also be useful in economics, as was shown in V.

(2) THE RENEWAL OF THE MENTAL TAPE

The renewal is necessary but may be a hindrance in our efficiency, especially in a transient state. This is clear if we look at the continuous renewal of the telephone number in Tokyo! Skill may be inversely proportional to the frequency of renewal. Also in management, the overrenewal of capital equipment is dangerous for enterprise. In our mental work a good management is necessary too for the renewal of our software.

Fundamental concept of physics like space or time may correspond to the capital equipment for the production of knowledge. In special theory of relativity Einstein tried a very important renewal. In the case of unified field theory, however, his trial was not so successful, as he anticipated. This reminds us of some poor management being too much hastened in renewal.

This renewal is not a simple logical consequence, because the *evaluation* of the effect of renewal is very important. We may call, on the one hand, the function of information processing "understanding", in which the necessity of renewal or its evaluation is out of the question. On the other, the mental function trying the renewal (Aufheben) may concern with the so-called "reason". I would like to leave such matters to philosophers.

(3) THE SENSE OF DYNAMICAL STABILITY

The sense of "dynamical" may be associated with the sense of action, which is produced by the movement itself. We can see an example of such a dynamical action when the movement of fluid in a hydraulic system is suddenly stopped. Then the fluid is strongly pressed by the force of inertia and in some case there is danger of explosion (waterhammer effect). Such a *dynamical behaviour* is different from the *system behaviour* of cybernetics. We must have "another training" (another kind of warming up) and cultivate the sense accepting such a behaviour.

There is no *difference* of level, if we stand and look across the river, because the difference must be equalized from the very nature of water. Nevertheless, there is a difference in the stream. There is a difference in the level or in the intensive factor which can be equalized (equilibrium coordinate) and in this case it is rational and necessary to avoid the useless stress. However, we must not forget the existence of another kind of coordinate, which is felt as the "contradiction". In considering dynamical stability of living system such a consideration is important.[10] About 1947 this author[7] was interested in such a consideration on social affairs but he was not able to consider the theory of *flexible throttle* or the system of parametric action and informational correlation at that time. Such a thought has developed since about 1957 or so and gradually became formulated. His paper[12] of 1961 is the first trial in this direction.

Cybernetic consideration is important but the sense of dynamical motion, which may be the antithesis of the sense of cybernetics, is also important.

VIII. *Cybernetics and Theory of Recognition*

There is an opnion[5] that cybernetics is a science studying the matter *common* to many field of sciences concerning information and control. In this report such a view-point is criticized as if picking the husks of the neighbouring fields and the idea of pure cybernetics was thus

proposed.

Scientists do not like to consider some thing like "general principle" originated outside of the proper field of science. They want to judge things only on their own ground. The general principle, if it is possible, must correspond to the real situation of the world.

However, scientists must be broad minded in accepting the *hearing aid* offered by cybernetics or by philosophy. In this report also many "suggestions" are given from cybernetic point of view, especially concerning social science. Cybernetics, however, does not insist the right or the function of decision, whether such a proposition is available or not. Such a matter must be decided by the science of the proper field. This may also be true to philosophy in the narrow sense. Cybernetics or philosophy may be an interpreter or a hearing aid. In physics the speaker must be phusis (nature) and the hearer mankind. Neither cybernetics nor philosophy can *modify* the speech of phusis. Considering this, the idea of the "general principle" common to many fields of research can hardly be accepted. We ought not to modify or to strain our recognition of phusis relying upon *inadequate* hearing aid.

There are many kinds of general principles in physics, like energy principle, the second law of thermodynamics, quantum theory and especially the electron theory of organic molecules etc., which are common to physics, chemistry and also to biology. However, there is the *material foundation* for such a generalization. Such a generalization is the matter of natural science and not of philosophy etc.

We saw another generalization like that of the idea of *system* in our society or the interpretation of our consciousness as the self-movement of mental software. We, however, have not yet sufficient material foundation for such a generalization. The origin of life and the evolution of human being may suggest such a possibility. The development of physiology of our brain and of psychology will make certain of such an interpretation, but this is a matter for the future. If we, on the contrary, deny such a scientific view-point, then we are in danger of falling into old idealism.[22] In this report, this author will push the cybernetic standpoint and take the following generalization.

At present, we will consider the *mathematical equivalence* only, which can be proved experimentally or by observation phenomenologically. The material foundation of such an equivalence is out of the question here. This is the idea of the black box or simulation, in which the system which are mathematically *equivalent* and different in *nature* are taken into account. This is the behaviour *common* to many fields in cybernetic sense. This may also be called "isomorphism". The training of cybernetics may make us well acquainted with such a behaviour, which is innate in every field, and make us easy to recognize it. This is the "generalization" in our sense, which was called "warming up" in this report. This is not a simple analogy, for the mathematical equivalence must be proved experimentally or by observation. Experimental evidence or observation only has the right to such a decision in recognition.

In this way the importance of the idea of *system* can be understood. Cybernetics want only to study the "system behaviour" and not the dynamical behaviour itself. The study of the latter must be transferred to that of *organization* etc..

According to the information technology "machine cannot create information". The negative entropy of information decreases, i.e. information only deteriorates through information processing. If the information of a sentence written in a language can be increased by translation, then the translator created his own, although influenced by the original one, and

has added to it. This may be a case of good translation of foreign poetry?

Information is obtained by measurement or by survey of the situation etc., i.e. information must be realistic and any fantasy during processing must be excluded. This is the spirit of modern science. This is very interesting from theoretical view-point of recognition.

Our experience is the window of knowledge as is well known. Every window must be equipped with a certain optical system, if the analogy is available. In the case of a pin hole camera there is no lense system and the image is correspondingly not so good. The better the optical system the better the image. The optical system is the product of modern industry, so that they are not *phusis*, although they are a kind of physical system. In some case we use a certain adequate filter or telescope to take a more realistic image. What the *adequacy* is, must be a matter of practice. There is no *a priori* right for any body to insist it.

Our mental window may also be equipped with reasoning power and our recognition is processed by it. This is not directly due to our "experience". A thinker, to whom we will refer soon later, considered that this is the meaning of "transcendental" but there is no *a priori* adequacy in our mental "optical" system. We ought not to dye the recognition by our subjective colour-filter. The adequacy of this transcendental function must also be proved objectively by practice as Marx insisted (see Note). Although we have nothing to know *a priori* concerning "Ding an sich", we can get more exact knowledge by using the adequate optical system, which was cultivated in our social life by the practice of *many* generations.

Note As there is feedback from the practice of our life, i.e. *feedback renewal* of our mental tape, the transcendental function must be under the influence of our life. On the contrary, our experience is mainly influenced by open channel of information. The classical theory of recognition of idealism seems to be due to the ignorance of the feedback consideration. Such an ignorance cannot, of course, be scolded, because cybernetics was not known at the age of Kant and other philosophers.

This was the idea of Tadasi Kato,[23] my old school mate, although he did not use the analogy of the optical system. He translated "Dialektik der Natur" of Engels into Japanese in 1929 and introduced this important thought at first into this country. In spite of his theoretical work he was not appreciated, while he lived. He was criticized and rebuked by his contemporary comrade. They called him "objectivist", although he was one of the most active person in the progressive circle. He was indeed active and faithful until his death in 1949. By his idea the "truth" must be *objective* and our recognition ought not to be strained by any ideology. If the analogy of the optical system is used, although he did not try such a thing, then we can say that energy is required to grind the lense system but the correctness of the optical system must, nevertheless, be scientific and objective. In recognizing the realistic situation we must be courageous. The energy of grinding may correspond to the courage and the recognition of the tendency of history moving forward may be the source of the courage. Ideology may also be the powerful source of such a courage and without it the exact recognition may, in some case, be difficult, because the optical system can hardly be ground without social energy. Nevertheless, the optical system is not the product of the energy alone. There is the matter of energy, on the one hand (see Note), and on the other the matter of information. If we consider a grinder controlled numerically, then the information controlling the machine is very important to get the exact optical system. Kato has stressed this in other words. He has imparted his thoughts to me in every detail, so that I feel I can understand his innermost heart[24] and so have tried to give the above interpretation. He was courageous in grinding his own mental optical system. This is the reason why he

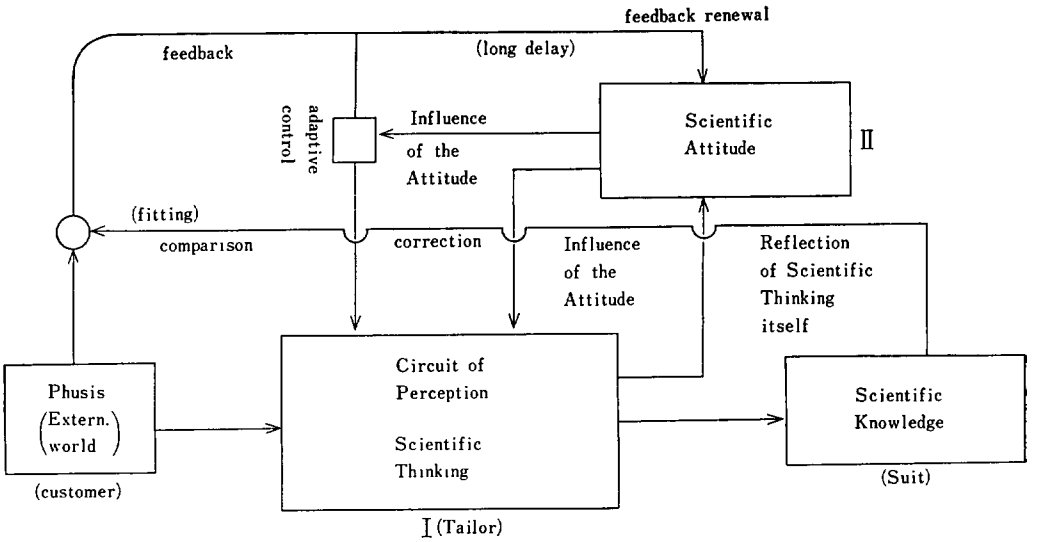


FIG. 7. FEEDBACK RENEWAL

Reflection of science may belong to the field of philosophy. Renewal of the scientific attitude is the feedback of the *indirect* type. On the contrary, the feedback of the scientific knowledge is the *direct* one.

I: this circuit is, as F. Bacon insisted, originally strained and disturbed by noise like *Idola*. Such a strain, however, is gradually corrected by the feedback, which is like getting fitted by the tailor.

II: in this circuit so-called transcendental intuition (space and time) and reasoning power are included. The transcendental theory of Kant may correspond to an approximate way of thinking that the delay is infinitely or limitlessly long.

could not stand aside from the social affairs at the time of postwar confusion, although he was already seriously ill.

Note In the case of sailing, the power for propulsion is of course necessary. If the engine stops, any information processing like steering is nonsense. However, the ship may be wrecked, if the information processing is *objectively* incorrect.

Those who have criticized Kato might have some confusion in considering the matter of energy and information, if we cite the above analogy, and they seemed to have adhere to the dogmatism that our recognition ought to depend on ideology alone. If so, they cannot be scientific as well as powerful, because the scientific exactitude may provide us with the most strong power "at the time when truth grasp the mass (Marx)".

IX. *Social Foundation of Cybernetics*

Cybernetics depends on the contemporary technological level (see III) as well as on the level of sciences, especially of biology or of physiology. The most important thing, however, must be the consideration of the development of social condition, which is expressed in short by

the name of automation.

Every nation is now experiencing a kind of social change and in some respect is in a chaotic condition. The underdeveloped countries are experiencing industrialization and deficiency in experts, so that automation in a different sense is required from the highly industrialized countries. Therefore, in every country there must be cybernetic as well as precybernetic condition.

Japan has an old-fashioned bureaucratism, which may be one of the most inefficient systems in the world. In its information processing there are always "large time delay", which is called "slomo" in Japanese. For this reason, I suppose, there is no *idea of feedback*, except the checking of the accounting. They are particular in the details of the procedure but less strict in the result. The office of private enterprises may be better, if we compare them with that of the government, but there are many points in common. The use of the Chinese character may be one of the reason, because mechanization of business is retarded seriously.

The production line of industry is partly modernized but partly old in which some sections are controlled by masters, who are like feudal lords having craftsmen in their hands. It is said that they do not want to tell the exact data even to their senior officials. This is also true in the case of agriculture, because every farmer must sell their crops to the government agency according to the fixed price and not by commercial transmission, if they give the true data. Statistics in Japan is highly developed in its theoretical side but the data gathering is not yet modernized because of the bureaucratism and of the delayed development of its society. This is one of the general characteristics of sciences in this country, where it is extraordinarily high in some levels while still standing on "foot of clay" in others.

Data processing in Japan, nevertheless, is a necessity for mechanization. If not, it may be paralyzed because of the increase of business accompanying the economic development. There is also the necessity of cybernetics, while there is also the residue of precybernetic condition, because of the delayed development of her society. This may be one of the main suffering in accepting the idea of American cybernetic management. There is also the lack of necessary education of personnel, especially in education of white-collar class and this is because of sectionalism in the intellectual world. For instance, the necessary education of computer analysis is retarded in Japanese Universities, although it is needed in society.

Japan imported the Western sciences in the Meizi (Meiji) era, about a century ago. At that time knowledge in every field was imported as a complete one and the mutual relation between different branches were neglected. Moreover, expert of each field made a gild and cultivated the people in a narrow minded way. Such a tendency was observed in education and in the worst form especially in that of the Imperial Universities. Scientists in Japan is of high quality individually but their mutual cooperation is very poor. There is no modernized system of cooperation amoungst the intellectual people in Japan, although there is splendid cooperating system of the craftsmen. This is why science in the intermediate fields like biophysics suffered so much in its early period.

Japanese thinkers in the field of philosophy are also living in a small circle without having intimate relation with scientists or technologists. Even in the field of philosophy there are many isolated circles. Some of them[1] recently met the work of the Soviet thinkers and seems to be disorientated, because cybernetics is a science of a very wide scope. This is the reason why cybernetics can hardly develope as a modern thought in this country.

Japan is now experiencing a social metamorphosis as was told in IV. In this connection

cybernetic consideration is very important. Bureaucratism, for instance, is a bottleneck of the modernization of Japan. Therefore, the mechanization of offices may be one of the important keys to the progress of our society. Thus the old-fashioned atmosphere will be modified.

There is an opinion that the modernization of Japanese enterprises make the revival of the capitalistic monopoly of Japan and strengthen it. This author, however, is of the opinion that the modernization strengthens not only the monopoly but the workers too, modernizing their mind. In this way the old-fashioned human relations which is called *onzyo* (warm heart)-*syugi* in Japanese may be abolished. If so, the consciousness as a proletariat may be clearer and the working class may also be strengthened. The shortage of the working population intensifies this condition.

Before the World War II social sciences in Japan were deformed by militarism. The postwar development in this field is remarkable, in some respect more remarkable than that of natural sciences in Japan! I am of this opinion as a physicist. In this situation cybernetics and mathematics may be mobilized as powerful "operation". The old-fashioned way of thinking of hesitating to study mathematics must be abolished. I should stress this as a biocybernetist.

The mode of thinking of the Japanese is now in some respect modernized. This is the difference from that of some underdeveloped countries, where even the development of capitalism is difficult because of the "old-fashioned programming" of their software. There are still large differences between the software in us and that of the Americans or that of the people of the USSR. Such a matter may be very interesting from the cybernetic point of view.

It is very interesting to notice that there is, I suppose, a tendency of penetration of the Western way of thinking in the Soviet Union, rationalism or pragmatism for instance, as was suggested or criticized by some Japanese thinkers.[1] Such thoughts were transported accompanying that of cybernetics. Some Japanese thinkers are of the opinion that this is not a progress of the Marxism but a retrogression. Anyway, the higher development of the Soviet society may be the foundation of such a way of thinking. I do not know whether the criticism of Japanese thinkers are just or not. However, I would like to comment on some thing concerning this, which makes me anxious.

Development as itself is good but there is a matter to be taken care of. In underdeveloped societies they must have a vivid feeling of "contradiction" or of "delay of logical consistency". They have the sense of dynamical power pushing history with blood and fire in the worst case. If their society is civilized or highly industrialized, such a kind of sense may be diluted and the rationalism is exaggerated. There may be only slight delay in logic, because of the developed power of fulfilling the logical consistency. Good is good in developed societies but good is not good in some societies, because things which are good as an idea may have bottleneck and can hardly be realized in many cases. During the War we, Japanese, experienced such a thing.[7]

Such a matter may perhaps be taken into account already by many thinkers. We must have reasoning power in highly developed societies too. However, there is certainly a danger in introducing cybernetics as a thought. I would like to stress this here.

If cybernetics is a science aiming to study the social dynamics, it would disturb the social sciences, whatever the standpoint or the ideology might be! This is why the idea of pure cybernetics was suggested. If we are considering it in such an abstract way, then pure cybernetics does not bring any confusion to our social thought.

X. *Concluding Remark*

In many cases it is said that our human society is living. Ordinarily this is considered only as a kind of analogy. The function of social mechanism, however, may be an *extension* of the biological life of mankind. This function can also control and mobilize the physical forces and energy parametrically, as in the case of law (see V) and the physical response may conversely influence our mind and thus make the social forces too. Therefore, there is a certain relation between the function of the social mechanism and that of biological life. This is not an simple analogy.

Cybernetics need not enter into the details of social studies. The modernized social sciences, however, must be equipped with the sense of cybernetics. For this purpose the education of cybernetics is wanted. There is, on the other hand, the antithesis of cybernetics, for instance the sense of "contradiction", which may be the driving power of the social movements. These movements are accompanied by the physical power as well as by the parametric action of human being. Cybernetics confines itself only to the study of the parametric action of certain pattern and to the system behaviour. So that it is necessary to avoid the narrow-mindedness in the education of cybernetics.

Besides mathematics, cybernetics has to be taught in high school and Universities in the near future. For the time being it must be taught by teachers of mathematics or of physics, who have the necessary knowledge of circuit theory, electronics, and the theory of feedback system. Moreover, a wide scope of cybernetics is wanted, because it is neither physics nor mathematics. The aim of this education is to warm up the mind of the students in studying any field of science, including that of social sciences. In this respect there may be some difficulty in getting the teaching staff.

In concluding it is stressed that to overcome such a difficulty may be of great importance in overcoming the sectionalism of the intellectual world in Japan.

In writing this report this author was instructed by many authors including Wiener[4], especially by Quastler,[25] Ashby[26] and Sluckin.[27] Concerning biocybernetics I am grateful to those[28]† who were kind enough to send me the reprint of their paper. In this report, however, I have mainly exhibited my own idea, which may, I am afraid, be dogmatic. I did so in hoping that such suggestions might somewhat useful for the study of social sciences, psychology, philosophy etc.

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† Receiving the information that Prof. Passynski has passed away, I must confess my deep sorrow.

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