P.J. Pretorius

HOMEOSTASIS AND CONTROL-INTEGRATION AS BASIC PRINCIPLES IN THE PHYSIOLOGY OF MAN

The word homeostasis, proposed by W.B. Cannon in 1929, is derived from the Greek word *homois* (– like, resembling, the same) and *stasis* (– standing, static). It denotes a condition of dynamic internal stability of a system by means of coordinated reactions. These reactions of the system compensate or neutralize any disturbing influence from outside or inside the system. These disturbing influences would otherwise change the normal structural and functional characteristics of the system. Two important aspects should be considered namely: (1) the aspect of internal stability and (2) coordinated reaction to assure stability.

The idea of regulation or control and coordination in living beings is not new. The basic idea is found in Chinese, Egyptian, Hebrew and Greek literature. According to Langley several physiologists were responsible for establishing the theory of homeostasis.

Sanctorius constructed his own clinical thermometer. In 1614 he described the fact that the human body kept its body temperature remarkably constant despite conspicious changes in environmental temperature. Claude Bernard, Pflüger and others described during 1850-1880 the ability of a living system to maintain a constant internal environment.

It is now generally accepted that the structure and functions of living systems in opposition to the non-living environment are governed according to the laws of homeostasis. In man diverse characteristics such as body composition, structure, mass, temperature, heart rate, blood pressure, blood composition, acid-base and ionic balance, oxygen, carbon-dioxide and glucose concentrations, osmotic activity, white and red cell counts, muscle tone, bodily posture, consciousness, sleep and wakefulness are kept within limits compatible with normal life. Even psychological

characteristics and personality are kept constant within limits.

Many investigators have tried to apply the principle of control systems and homeostasis to the higher mental, intellectual and spiritual functions and even to sociology, history, economy and politics.

A typical example of a well-known phenomenon is the uniqueness and constancy of the fingerprints of an individual. Each individual retains his basic bodily and mental characteristics despite environmental changes and threats. This basic principle applies to all tissues and organs but not in the same degree. The limits of range of variation vary.

Dynamic changes are obvious in the living as well as the non-living world. In nature continuous material and energy changes take place, for example:

(1) The dynamic movement of the planets round the sun. This dynamic movement is essential for the maintenance of the structure of the planetary system.

(2) Energy release by the sun is essential for the supply of energy to living organisms on earth.

(3) Biological processes exhibit dynamic activity according to their own nature. For example the structural material of organs like muscles, liver or heart is replaced by other similar building material within a few weeks. This dynamic transfer of material from ingested food is a continuous process. Because of this exchange of building material, catalytic substances as well as energy, the living organism is intimately dependent on a constant supply from the environment. This continuous and simultaneous process of breakdown and rebuilding or synthesis of tissues and organs is called metabolism. An exact balance between breakdown and rebuilding gives the impression of a static condition. Actually this appearance of a stable condition is misleading because even the building material of the most stable part of the living body, the skeleton, is continually replaced. Within a few months most of the original calcium in the bones is replaced by "new" calcium derived from the diet. These facts stress the importance of a sufficient and well balanced diet. This proves the

intimate interrelationship between living and non-living things and the impossibility of any stable autonomous existence.

Things in nature appear to be static or stable

Except for small gradual changes in structure and functioning during aging the human body remains the same. For example fingerprints do not change despite the fact that the upper layers of the skin are continuously rubbed off and replenished by means of cell division from the deeper layers.

In contrast to the tread of a tyre of a motor vehicle the fingerprints of hands and feet do not wear off but instead will grow thicker when the external wear factor is increased within certain (physiological) limits. More or less similar to the skin, but not always by means of cell division, the organs and tissues of the body are kept in a dynamic equilibrium between breakdown of structure and rebuilding or synthesis. There is no physiological answer to the question of why this dynamic exchange between living beings and non-living environment takes place. Despite threats e.g. energy changes in the environment, a living body maintains its characteristic structure and functions.

As long as this dynamic equilibrium is precisely maintained the outward appearance of a static unchanging living body is preserved. Thus it is possible to recognise a well known adult person after a long period of absence such as, say 40 years. He may show signs of aging but on the grounds of his basic features he may still be easily recognised, his fingerprints will still be the same. This proves the efficient and precise way in which the replacement of building material is controlled in the body. This gives the impression of a static state.

In the same way the human body-posture and balance is maintained. Many gravitational opposing forces are evoked by muscle contractions on all sides of the body to maintain the erect position. This dynamic equilibrium between gravitational and anti-gravitational forces is not obvious in the standing person. But precise and continuous control by means of receptors, nerve cen-

tres and muscle is essential to maintain this important function of the body. Ecological systems are maintained in much the same way. Despite continuous change a dynamic equilibrium is maintained.

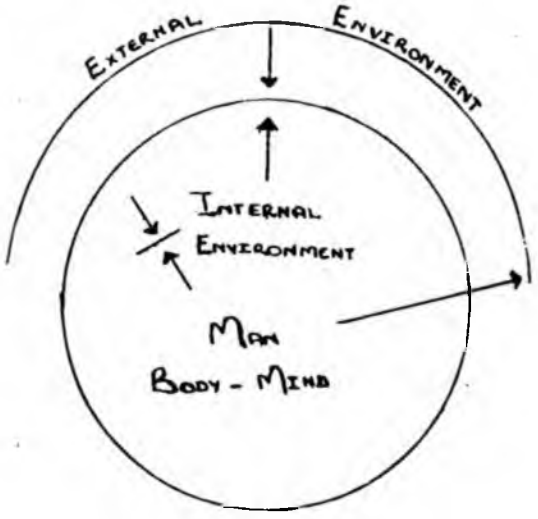
Does the same apply to the non-living world, sun and planetary system and the atomic structure? Dynamic movement despite a superficial impression of stability. Precisely balanced opposing forces in a dynamic equilibrium.

How a dynamic equilibrium is maintained

Each existing dynamic equilibrium in the human body is essential for the maintenance of a specific structure and bodily function. Dynamic equilibria are not maintained spontaneously but depend upon control mechanisms which function according to the laws of control systems.

As an example the relationship between man and environment can be taken. This can be presented as the over-simplified model in Figure 1.

Figure 1



Two environments should be considered, the external as well as the internal environment. The internal environment constitutes the external environment for the cells of the body. To secure normal structure and function of the cells it is important to maintain an optimal internal environment. Every threat of change or deviation from the normal optimal physical or chemical constitution of the internal environment must be averted or prevented. Threats of deviation from the external environment (Figure 1), (1) are opposed or counteracted by means of resistance from the body's control mechanisms. The same applies to the threat of disturbance from the internal environment (Figure 1), (2). These resistance or defence mechanisms are controlled in order to maintain the normal structure and functions of the body. The ability to change the environment is represented by arrow 3 in Figure 1.

In its simplest form a living resistance or defence mechanism can be represented by a model such as a negative feedback control mechanism. Such a negative feedback control system will react to incoming information about an imminent change by offering resistance in the form of a suitable and adequate opposing or counter-performance. In an ideal situation this counter-reaction will cause a precise balance between the imminent threat and the resistance. In other words all the physical and chemical characteristics of the threat will be exactly warded off. This applies to many characteristics of a change or stimulus such as the total intensity, duration, rate of change, the nature, locality etc. If the correction of a deviation caused by a control system is more or less than the actual deviation, an overreaction or an underreaction of lesser degree will still persist, in other words a residual deviation. E.G. if the environmental temperature decreases at a certain rate to a certain minimum value for a certain period, the human body will react by means of all its resistance mechanisms to counteract this threat. All the receptors will send information to the different control centres of which the nervous system is the most important. The reactions will be diverse and influence the whole body because the nervous system has overall

control of the body, thus the skin, circulatory system, respiration, skeletal muscles, endocrine system, behaviour as well as intellectual abilities will all be put into action to conserve body heat as well as to produce more heat. The basic structural components of a control system are: (1) receptors for observing a change or coding of information, (2) a control centre for the integration of all relevant information and comparison with a standard value or norm, to determine the deviation from the standard and eventually to programme a counter reaction, (3) a motor or executive system to perform the counter reaction. Important is the correct reaction concerning (1) nature of the threat, (2) rate of change, (3) intensity, (4) duration. For a perfectly balanced dynamic equilibrium to be obtained all parts of the control system should operate in a perfect way, i.e. receptors, centra, effectors, transmission systems, energy conversion. Most of the less complex control systems in the body do not function on the basis of anticipation of a future change but are initiated by the residual deviation. The ideal control system is one with the ability to anticipate a future imminent threat. In this way changes can be avoided or reacted against in a more precise way.

An important question is to what extent can these principles of control systems be used as a model to study the human being. In human physiology the model of control systems is applied to investigate and explain most of the fundamental phenomena e.g. control of body, organ, tissue and cellular structure and functioning, as well as in explaining integration of functions into a unity on all levels of structural arrangement. It is even applied to explain behaviour and intellectual functions of the nervous system as a control system. From this point extrapolation is made to society, education, history, etc. Much impetus for this way of thinking was derived from the ideas of Wiener, Steinbuch, Klaus and others.

A few examples may illustrate this idea. This idea of control is not new, the Greeks had the idea that the whole universe is a big complicated machine. Descartes (1662) stated that the human body is a machine except for the pineal body which he regarded as the site of the mind, soul or spirit.

1. Human physiology

1.1 Genetic control

The molecular microscopic as well as macroscopic structure of cells, tissues, organs, systems and the body as a unity is maintained by genetic control in the first instance. The basic genetic ground plan determines that there will be constancy and maintenance of normal structure. This negative feedback control assures that despite the dynamic turnover of matter the structure will be maintained, e.g. fingerprints, facial features, etc.

1.2 Immunological reactions

The body reacts to threats by micro-organisms, toxins, viruses, foreign proteins etc. by the production of immunological substances. In this way an effective resistance to infection is obtained. In the same way that genetic control is directed towards the goal of maintenance of the structure, so is immunological control directed towards securing health and survival of the individual.

1.3 Reflexes

Control mechanisms can be regarded as a very good approximation of a reflex action. Reflexes are goal seeking, each one has a definite purpose, e.g. control of specific functions such as blood-pressure, muscle tone, protection against harmful stimuli etc. Receptors are responsible to detect environmental changes, these are "coded" into nervous information which is interpreted in a control centre in the spinal cord or brain where a reaction is programmed and which is then carried into execution. This reaction is always opposite to the threat in order to resist any change in body composition or structure.

1.4 Brain and spinal cord as control centra

The brain and spinal cord can be presented as a complicated control system by which the whole body is integrated into a co-ordinated unity. The brain receives all the incoming information concerning changes or threats from the outside as well as the inside environment. This includes many and diverse sources and modalities of information e.g.:

(1) From the internal environment: changes in blood-pressure, acid-base balance, temperature, osmotic pressure, electrolyte composition, muscle tone, displacement, velocity and acceleration of joint and muscle movement, orientation of the body in relation to gravity forces, oxygen, concentration of hormones, etc.

(2) From the external environment: light, temperature, smell, taste, mechanical stimuli. The changes include physical, chemical, biological, psychological and intellectual stimuli.

(3) Autonomic, spontaneous activity of the brain and spinal cord. The brain exhibits this ability of automatism more than any other part of the body. This ability is inherent in most cells and organs e.g. the sino-atrial node of the heart which acts as pacemaker. The inherent spontaneous pacemaker activity of the brain may explain the ability of the brain to create new ideas. This is the most complex and least well understood function of the brain. In this respect it does not fit into a simple model of a control system. The proposed model for pacemaker activity is based on the idea of automatism and autonomic functioning.

The brain integrates all the above-mentioned information from the three main sources. Two possibilities exist namely that a reaction will be formulated and executed or that no action will take place. Three types of motor or dynamic bodily reaction can take place. In most cases all three reactions will occur simultaneously so that the body will react as a whole unit. The three motor output reactions are:

(1) Autonomic nervous reaction mediated by means of the limbic part of the brain including the hypothalamus and the sym-

pathetic and parasympathetic nervous systems. Emotional, behavioural and visceral bodily reactions are controlled in this way. Smooth muscle and glands are thus controlled. Many organs and systems are affected e.g. heart and circulation, blood pressure, gastro-intestinal system, respiration, metabolism, etc.

(2) Endocrine system. By means of integration of the limbic system with the hypothalamus and hypophysis the whole endocrine system is integrated under control of the nervous system. In this way every cell in the body is under direct control, so that the chemical and physical functioning of each cell can be influenced in order to secure dynamic equilibrium and to serve the purpose of the whole body: to reach a certain set or planned goal of higher order.

(3) Skeletal muscle activity. The brain initiates and controls many voluntary muscle movements. This is made possible by means of different cooperating systems so that each voluntary movement is simultaneously accompanied by coordination of muscles by means of coordinating brain centra and spinal cord reflexes. Each voluntary motor action in connection with any human activity such as intellectual expression in spoken or written words or any product of art is mediated by means of this system of motor brain centra, coordinating centra and reflexes.

The brain is the highest control centre for integration of all the above-mentioned functions of the body into a unity. In this way a human being will always react to most environmental changes as an integrated unit. It is possible to perceive the human being as a unity consisting of different levels of control which are arranged in an integrated interacting whole. On each level the unique regulatory and goalseeking characteristics of the control systems operate. By means of analysis these typical characteristics can be investigated. The method of analysis however, tends to disturb and even disrupt the link between adjacent, higher, or lower levels of control. The result is that the effect of interaction between the different levels of control is deformed or eliminated. This may cause a caricaturish, robot-like or synthetic image of the real function of this level of control in the

integrated whole of the body. E.g. the "autonomy" of the SA-node of the heart as pacemaker has been known for more than a century. This phenomenon is known as automatism. It is however realized that in the normal body this characteristic of the heart in controlling itself by means of the SA-node is never encountered. The heart is under the constant continuous control or modulation of the nervous system. The same applies to the relationship between analytical information about basic reflexes and the tremendous overriding modulating and integrating effects of higher centra in the brain. Uncoupling of the interaction between higher and lower reflex control usually causes a change of both control systems. Under experimental conditions analytical procedures may "liberate" a lower control system from the higher integration.

Many controversies have arisen concerning the importance of basic analytical cellular or organ control mechanism theories and the role of integration by control mechanisms of a higher or adjacent level, e.g. the importance of self-control in the heart, also known as the Law of the Heart or Frank-Starling Law, in relation to nervous control by the autonomic nervous system and higher brain centra. Thus two functions should be considered namely (1) control at different levels, (2) interaction and integration of the different levels of control.

1. The different main levels of control in man can be analysed as follows:

First level: Genetic control: Bv means of genetic control the structure and basic functional characteristics of each cell, tissue, organ and system of the body are controlled. Despite many threats such as mechanical, osmotic, thermal, and dynamic turnover of building material, the structure is maintained. There are some threats like ionizing radiation which may change the efficiency and even character of the genetic control system.

Second level: Hormonal control: The basic structure of the

endocrine control system is determined by genetic control. The hormonal control system is able to modulate the structure and functions of almost every cell in the body. In this way the functions of every organ are directed towards a certain goal. Within the genetic control limits a wide range of change in structure and function is possible. Proof of this is the tremendous changes in body functions during diseases of the hormonal system, e.g. diabetes mellitus, cretinism and acromegaly. The facial features of a person suffering from acromegaly may change to such an extent that the person will not be recognizable after a few years. Defects of sex hormones may cause a change in secondary sexual characteristics from female to male and *vice versa.*

It is also well known that hormones have a dramatic effect on the nervous system and even the higher centra of the brain. In this way an interaction in both directions occurs. Hormones do influence emotion, mood, behaviour, personality and intellectual ability, just as these are co-determined by genetic control mechanisms. Hormones can be classified into two or three groups e.g. (1) those causing growth, energy conservation and depression of activity and emotional mood, (2) those causing energy release, increasing vigor and activity with euphoric effects and feeling of well being at the emotional level, (3) hormones with specific metabolic or cellular regulating effects with mixed or no clearcut effect on mood.

A plant possesses only these two control levels namely genetic and hormonal. All the structural and functional characteristics of a plant are controlled by these two systems, in response to environmental changes such as light, gravity, mechanical, climate, etc. In this way structure, functions and survival are secured as far as possible. If a threat is too big it will cause serious damage or death because the ability of the control systems to resist is exceeded. From an analytical point of view the endocrine control can be described as a negative feedback mechanism with the goal or purpose of controlling structural and metabolic activity according to the genetic nature of the living being and in relation to changes in its external and internal environ-

ments.

On the other hand, viewing the endocrine system from the integrated or unitarian point of view, it is quite obvious that the endocrine control does not possess autonomy except in the plant or in experimental or disease cases when it is uncoupled from the higher control mechanisms.

The nervous system possesses an initiative and modulating influence upon the endocrine system. Thus despite the fact that the hormones influence the nervous system it can regulate the endocrine system by means of negative feedback and in relation to the genetic characteristics and environmental changes. An integrated interaction exists with the nervous control as higher level. Much misunderstanding about the functions and general role of endocrine control in the human being has been caused by misleading applications of the dogma of the evolution of man. It is becoming clear now that the dogma of evolutionism is too limited to explain all the available facts and that it hampers further investigation.

Third level: Reflex control: All the so-called voluntary movements of an animal or human being are controlled by several reflex mechanisms. No motor action is possible without reflex control. Most of the visceral control of organs and systems depends on reflex control from the autonomic nervous system. In all reflex control analytical information clearly points to the negative feedback control nature of reflexes e.g. control of bloodpressure, heart rate, respiration, digestive functions etc. Reflexes of different degrees of complexity exist. The simplest, like the stretch reflex, may contain only one synapse and two nerve cells (neurons), in complex reflexes there may be many synapses and many nerve cells. Different ways of processing of information are possible because of the arrangement of nervous circuits e.g. a diverging circuit is responsible for amplifying, a converging circuit for integration and circular or reverberating circuits for repetition or rhythmic action etc. Two basic synaptic functions are always in operation namely stimulation and inhibition. By means of circuit arrangement and synaptic effects many nervous functions can be explained and simulated. These include integration, com-

parison with a constant or norm as well as the use of previous information by means of memory mechanisms. All these functions are used to programme and perform a suitable resistance reaction. Basic simple reflexes may be elicited when the spinal cord is separated from the brain. These spinal reflexes are then uncoupled from the integrating influence of the higher centra. Most of these spinal reflexes never occur in this caricaturish or robot-like way because in the integrated whole its function is drastically changed, by modulation and integration.

During uncoupling the basic reflexes may become autonomous and this causes loss of the integrating higher purpose or goal-seeking control of the higher centra. This bring about a very clearly visible conversion or degradation of the reflex into a machine-like or robot-like functional control system. Only then is the simple negative feedback nature of a reflex visible and the basic goal or purpose, e.g. simple coordination by receiprocal inhibition, control of muscle tone, protection against harmful stimuli, control of heart rate, Starling's law of the heart is only obvious then.

Under normal conditions however, the functioning of the spinal cord reflexes is integrated by means of higher centra e.g. medulla, brainstem, midbrain, basal ganglia, brain cortex. Higher centra for example integrate several spinal reflexes in unison to react against the forces of gravity. In this way muscle tone is modulated in such a way that the body maintains its position despite the constant threat of loss of balance.

Reflexes thus control motor activity of skeletal as well as smooth muscle and also control glandular secretions in an integrated whole and never as autonomous control mechanisms except in simple animals or during disease or experimental conditions.

Fourth level: Emotion, behaviour and instinct: Different brain centres are responsible for the coordination of bodily expression of emotion. In more complex animals this level of control is the most important higher centre. All the motor activities in these animals are integrated by means of behaviour control, such as feeding, reproduction and territorial delimitation. The activity

includes all "feelings" or urges such as hunger, thirst, feeding, etc. and the carrying out of feeding procedures, all the bodily functions in connection with reproduction, mating, building of nests, care for the young, all bodily changes during aggression, fright, etc. Many higher control centra, such as the limbic cortex of the brain, hypothalamus, autonomic nervous system, endocrine system are integrated. All these control actions can be seen and explained on the physiological pre-assumption of homeostasis, for example limbic control is only a higher level of control in which not only the survival of the individual but the survival of the race or species is the main goal or purpose. The important question is whether this simplified model or working hypothesis, which is designed from the basic assumptions that man has evolved from a simple form of life and that the human being can be fully explained and even be simulated by a cybernetic physico-chemical (or biophysico-biochemical) model, is accurate. Most of the modern physiological textbooks take this idea for granted. This has led to some of the older misunderstandings about the ideas of Freud.

Fifth level: Intellectual control: In the human being the limbic part of the brain cortex controlling emotion and behaviour is relatively small, (less than a quarter of the surface). A much greater part of the cortex in man is occupied by the neocortex (neopallium). (The term neocortex is derived from the assumption that in the process of human evolution this part of the brain is the newest development or addition). In primates more than a third to a half of the cortical surface is occupied by the limbic cortex, in a rat about three quarters to four fifths of the surface is occupied by the limbic cortex. Mass and surface differences are an indicator of differences but not of prime importance. Of more importance are the functional differences. According to the homeostatic mechanistic and bio-control hypothesis the following model can be constructed.

The intellectual functions and abilities of the neocortex of man enable him to plan for the immediate as well as the distant future. In this way he can prepare himself for future changes and threats. This preparation includes training and education. All in-

tellectual activity can be fitted into this model. E.g. medical research and training in order to provide knowledge and techniques to maintain the internal environment of an individual optimal and constant. Of prime importance is preventive medicine to help the body to maintain a high degree of resistance. We need much more knowledge about diet, sport, medicine, standards for a healthy way of living to increase the quality of life, to increase intellectual ability, to increase the power to resist disease and the effects of aging etc. In this way we will be able to survive and to maintain a good life not only for the individual but also for the human race. In the same category lies the study of ecology and efforts to fight pollution of the environment because these are directly connected with human survival. The same applies to any other human cultural endeavour such as agriculture, economy, futurology, politics, organization of society, a state, etc. Of key importance are all environmental, human and life sciences and technology.

The highest brain cortex enables man, by integrating the whole body with all its functions, to survive as individual, family, society, nation, human race. This integrating ability on the highest level focusses attention upon the unitary organization of man.

2. Integration of the different levels of control

According to the homeostatic or biocybernetic hypothesis the human being can thus be regarded as an integrated unity consisting of a certain special type of interacting hierarchy of different levels of control or homeostatic resistance. On each level of the existence of man a suitable control mechanism is operating to secure survival. A wide range of the physical and chemical nature is under precise control in the human being. All the atoms, molecules, cell organelles, cells, tissues, organs, systems, body, family, society, culture, human race, biosphere, earth, outer space, in fact, are controlled.

In the human body there exists a specific type of hierarchy of control, consisting of genetic control over the basic structure, hormonal control over metabolic processes, reflex control for dynamic motor control, behaviour control for emotion, feeding, reproduction, intellectual control for cultural, scientific, creative planning. In this way man has control abilities over the non-living material world as well as over the living, plants, animals and himself. Each control level has its own range of control or functional domain or sphere of authority. When a control level is uncoupled from the higher level it will act autonomously and thus will give the impression of a robot. In other words the higher control level goal or purpose will be lost. The higher meaning of the control system will be lost and will then perform a lower control over a minor or "lower" goal and the control system will serve a lesser or "lower" purpose.

A virus possesses little more than genetic control, a plant only genetic and hormonal control, an animal, genetic, hormonal and behavioural control: man possesses all the levels of control plus intellectual control. The same can be seen in the functioning of the human body. The cells of reproduction are the main carriers of genetic information. Almost every cell of the body could be isolated and kept living in a culture medium. Such a cell will survive and will perform most of its basic cellular functions, its own control mechanisms will secure its unity as a living system. The same applies to isolated tissues and organs, even systems. The isolated heart will continue to beat when isolated if it is provided with suitable environmental factors like fuel, catalytic substances, temperature control etc. But the goal or purpose of this beating heart has changed. It is now a physiological preparation to be used in an experiment etc. It is no longer integrated into the whole body of a man working to earn a living so as to care for his family or that of a soldier defending his country. It does not serve the body as a whole any more. The same applies to the cells of the heart. E.g. the pacemaker cells generate heart impulses at a rate of 90-100/min to keep the heart beating. These cells have the purpose of keeping the heart beating by controlling

the basic rate of the heart. In the whole body their rate is modulated by nervous control so that the heart beats at 70-80/min. The isolated heart will thus beat at a higher rate – 90-100/min. When these pacemaker cells (SA-node cells) are isolated they will continue to beat under the control of their own cellular impulse control mechanisms. But the purpose of these cells is no longer to keep the heart beating. The cells can be analysed further and the function of each cellular component can be studied, e.g. the sodium and potassium transport abilities of the cellular membrane are of prime importance in evoking the heart impulse. This sodium and potassium ion transport is under the rhythmic control of membrane structures such as membrane enzymes. These enzymes are synthesized under precise genetic control.

On each level of control a very specific goal is aimed at or a clearly defined purpose is served.

The goal of this genetic control of the SA-node cell membrane is to regulate the synthesis of enzymes of a specific kind to transport sodium or potassium. In the whole body this serves the higher purpose of causing heart impulses to keep the heart as an organ beating. The beating of the heart again serves the higher purpose of circulating blood to maintain the important functions of the circulatory system. The purpose of the circulatory system is to secure an optimal internal environment for the living cells and to enable the brain to function. The heart and circulation is under control of the autonomic nervous system, the purpose of which is to detect threats of changes in the internal as well as the external environment, and to react to secure survival of the whole body. The autonomic nervous system is again functioning in close association with the limbic system with the aim of performing behavioural functions like feeding, reproduction and emotional effects. Finally the neocortex integrates all the above-mentioned levels of control in order to fulfil a higher purpose e.g. the work done by a man to earn a salary so that he can care for a family, etc. In the integrated whole all the control levels are in action but not as autonomous isolated entities. By analysis and isolation the effects of higher integrating control levels are lost

and the higher purpose is changed. This does not mean that the chemical nature of sodium is changed inside the body. The sodium that is taken in the daily food serves the purpose of causing heart impulses in the SA-node or nervous impulses in the nervous system etc. This has the purpose of keeping the heart beating and maintaining conductibility in the nervous system etc. This serves the purpose of every other level of control in its own domain. Thus a relation exists between diet, sodium, cell membrane activity, cardiac impulses or nerve impulses, circulation of blood, brain activity, behaviour, intellectual functions, thought, memory, creativity. Sodium plays an important role in the human being. The whole as a coordinated integrated unity can serve a much higher purpose than the total of uncoordinated sub-units.

The question is what this higher purpose is. According to the bio-cybernetic or homeostatic approach the sole purpose of all living beings is survival and maintenance of life. This is a law of nature. In other words there is no difference between the basic purpose of a living cell of a plant or animal and man. It is only a matter of more complicated control. The intellectual abilities of man provide the possibility of organising society, of changing history, of planning the future and of changing man to fit into a well planned and organized society. This should be the main short term purpose of human endeavour and in this respect the study of the functions of the human body is of the utmost importance. On the long term not only survival but a high quality of life should be striven for.

The work of scientists like Wiener and Steinbuch supports the idea of the application of information and control theory on a wide scale in society. Science is an instrument by which man can master control over nature. Its great importance cannot be denied e.g. in medical and life sciences, physical and mathematical sciences, psychology, sociology, education, economy, etc. But could this really be the highest purpose of the life of a human being?

1. Physical, chemical and mathematical sciences

The study of control systems in conjunction with a study of human control mechanisms is important to develop robots, to automatize processes. The development of computers with more human abilities e.g. more learning and predicting abilities is of importance for application in several other fields like futurology, economy etc. The effectiveness, safety and dependability of many man-machine relationships can be improved by these developments. Automatic machine control adapted to human shortcomings is important.

2. Medical and human life sciences

The basic principles of homeostasis and control systems are important for medicine and life sciences e.g. the defects occurring in control systems.

Defects include: over- or under reaction, oscillation, delayed reaction and vicious circles.

(1) Over correcting (over reacting). A threat is observed correctly but the resistance which is programmed is more than needed to balance it. The reaction will then cause a deviation of the threat to the opposite side. This new threat again causes a second counter reaction. Oscillation can be caused in this way. In some organs and cells this is a unique physiological characteristic e.g. the generation of the cardiac impulse depends upon the rhythmic change in stability of the SA-node cell membrane for sodium permeability. This "sodium-balance" is like a pendulum moving to and fro 70-80 times per minute for 70-80 years.

(2) If undercorrection occurs, the deviation-threat is decreased in insufficient degree and will still harm the body by changing the internal environment to above or beneath the physiological limits for optimal functioning. This is usually the case when not enough energy is applied if the resistance mechanisms of the control system are in any way decreased e.g. by ageing, dietetic deficiency, intoxication, etc.

(3) Delayed reaction can occur when any part of the control

system develops a delay in the communication of information. This may be caused by any part of the system e.g. receptor, centre or motor effector.

(4) Whenever a positive instead of a negative reaction is evoked by the control system this will cause an increase in the threat or deviation instead of a counter-reaction. This will cause a snowball effect which can be lethal.

All diseases can be viewed as defects in one or more control systems of the body. Good health can be viewed as optimal functioning of all the groups of control mechanisms. Two types of possible defects can occur namely (1) defects on each level of control i.e. genetic, hormonal, reflex, behaviour, etc. (2) defects in the integration of the different levels of control i.e. in the harmony of the whole body as a unity.

1. Defects on each level of control

On cellular level genetic and intracellular control is important and defects will cause serious changes. Cancer may be regarded as derangement of the basic cellular control mechanism causing a positive feedback so that cell division will continue uncontrolled. Immunological control of resistance to infection can be regarded in the same way. Many examples of defects of hormonal, reflex, behaviour and intellectual control are known.

In most cases the pattern of over- or underreaction, oscillation, delayed reaction or positive feedback can be detected. Overwhelming threats imply that the normal resistance of the body cannot cope with the change in environment, this can be defined as a danger. If a threat is within limits it can be viewed as a challenge. The body needs challenges of physiological modality, intensity and rate of change, challenges help to keep the resistance control systems fit. For any human endeavour it is important to determine the risk factor i.e. the sign of the difference between challenge and danger.

Defects in control can be caused by external as well as internal disturbances.

2. Defects of integration of different control levels

When the functions of a higher control level are eliminated by uncoupling or cessation of functioning the lower levels will continue to operate but in an unintegrated or autonomous, robot-like way because of the loss of higher purpose, e.g. when the brain cortex is dead, a person will be unconscious and intellectual abilities will be lost. But if the brainstem is still functional the respiration, circulatory control, endocrine control, genetic control will still operate and keep the body living by their homeostatic functions. When the brainstem is also dead the body will be in need of artificial mechanisms to control respiration etc. but the organs, tissues and cells will still operate by means of the lower control mechanisms. A very close interaction between higher and lower control levels exists. Many diseases of body and mind can be related to defects in this harmony.

In any treatment of disease it should be kept in mind that both the specific level of control as well as the integration of levels may be affected. An effort to correct a control defect on a specific control level may cause disintegration or disharmony or change interactions or may change other control systems. Hormonal control defects may cause emotional control disturbances. Many medicines have side effects because of influences on other control systems or on the interaction between control systems.

The above-mentioned defects in control systems should be kept in mind. This is probably the main deficiency in the basic hypothesis of homeopathic medicine, namely that it presupposes the intactness of the functioning of a control mechanism and that treatment is directed towards eliciting the body's own resistance by challenging the control system. This will only lead to success if the specific control mechanism is able to function.

3. Ecology

In the field of ecology the principles of biocybernetics are well appreciated e.g. the unity of an animal colony is regulated by the

same negative feedback control as well as by interactions between different control levels. Each individual animal e.g. ant or bee, possesses its own genetic, endocrine, reflex and behaviour control to secure its own survival, feeding, reproduction etc. but the colony as an unit has its higher levels of control to secure the survival of the whole, e.g. sacrifice of the life of the individual on behalf of the colony can occur.

Control system analysis is an important approach to the investigation of the factors which determine the relation of individual living organisms to their environment as well as interrelations between individuals and as groups.

For the maintenance of a favourable optimal environment for human life in the future and for conserving nature in a purposeful, responsible way it is important to study these regulatory mechanisms. This will enable man to control a dynamic ecological equilibrium with himself and all his cultural scientific and technological activities in harmony with a "cultured" nature as one controlled unity. Futurology has this aim as its main purpose.

4. Psychology, economy and sociology

Emotion and behaviour are primarily controlled by the limbic cortex of the brain by means of the different brain nuclei like the hypothalamus and autonomous nervous system. On each level of control a negative feedback mechanism is operating e.g. to enable the body to respond to emotional stimuli. In many instances these reactions are simple resistance reactions. This is noticeable when the influence of the neocortex is inhibited or eliminated. In animals for example, fight or flight reactions and aggression are mostly directed towards survival of the individual or reaction towards a threat or supposed threat. The same applies to behavioural patterns for feeding, reproduction and territorial delimitation. In many instances humans react in the same way to new situations and these resistance reactions may assume different forms, mostly either inhibition or excitation.

Oscillations are characteristic of the state of mood, with a range from depression and pessimism to cheerfulness and optimism. Many factors influence the basic mood control mechanism e.g. genetically determined control ability or tendency toward one or other extreme; hormones; changes in the acid-base balance of the body, or other changes in the internal environment; substances in the diet, etc. Most diseases, toxic substances and medicines affect mood control systems. The integration of mood control by the intellectual control gives a higher purpose to it and can cause dramatic modulation. Many psychological disturbances exhibit the basic characteristics of deranged control or control-integration.

Previously too much accent has been laid on either behaviour control or external stimuli. Human psychology is much more complex than simple behaviour. In our present day society much use and misuse is made of these facts concerning simple behaviour control.

In any organization or industry negative feedback control is of basic importance. Different levels of control are created to provide for different functions. On each level responsible "governors" or leaders must control activity such as production, standards of work within certain limits. Information flow in specific directions is very important. Feedback control provides the information for comparing the actual performance of a control level with the ideal standard. Adequate corrective measures must be taken for every deviation. For a well organized system, harmonic integration of every level of control is important, i.e. these principles are of utmost importance in any economy. Intensive study is being made of information and control systems and of their application to economic problems.

In every society or sub-culture certain standards or norms based on religious, moral, ethical, or traditional values play an important controlling role. By means of negative feedback, resistance against change exists whereby the identity and specific character of a group or society is maintained. Deviations are corrected and stability is obtained by means of a dynamic equili-

brium.

An important question again is what is the purpose or goal of many of these control levels in the emotional, psychological, economical and sociological activities of man. Are they directed towards survival only? Survival of the individual on a selfish basis, survival of the family, group, sub-culture or the nation as a unity?

The study of these disciplines may only be directed towards greater human governing power by the more efficient use of control mechanisms on each level. In future science may teach man for example, to control emotion efficiently, to eliminate aggression and violence because it can efficiently control genetic, hormonal, reflex and behaviour control systems. Aggression can be seen as a serious threat from the internal human environment. Should the individual be adapted or modified to fit into a well organized society, the individual could be content, happy, motivated, to serve the human race, nation, society and to do his part to secure the survival of the human race? A controlled society could be the goal of a cybernetic philosophy with a behaviouristic or mechanistic approach towards the study of man.

5. Education and politics

Homeostatic control theory has important implications for education and politics. Education is dependent upon the principle that information can be taken up by means of receptors, integrated and processed and assimilated, memorized, and that a response or reaction can be programmed. The over-simplified idea of the behaviouristic approach obtained new impact in bio-cybernetics. Education from a control system approach has two goals: (1) the training of a complicated human control system to perform more efficiently, (2) the alteration of the behaviour of the control system in a favourable way, i.e. a change of the "programme" of the control centre for instance by changing the norm or standards.

Three levels of education can be visualized:

(1) Observation of changes or information input. Sense-organs play an important role in this respect but so do the entire sensory, integration and memory functions of the nervous system. Precise observation, memory and reproductive abilities should be trained, (2) integration at the control centre level, compilation of an integrated whole or over-all view, assimilation of information and application of relevant information, solution of known problems, (3) reaction ability or creativity including the training to react in an efficient way to certain situations and problems. This implies the solution of new or unknown problems and the invention of new ideas.

Typical defects of control systems are often encountered in the education of young people. Poor observation, insufficient assimilation and integration of information, poor reaction abilities because of improper learning, motivation, interfering influences etc. Over- or under-reaction, vicious circles are always present in the educational situation. Too often the student or pupil regards a new lecturer or a new task or a new approach as a threat. This image can easily be reinforced by a teacher who also approaches the new task or situation as a threat to himself. The pupil will resist because of negative feedback control. His own personal "survival" resistance will then hinder integration into a higher control of cooperation with the teacher. On the other hand if cooperation could be obtained, all control mechanisms could be harmonized into an integrated education-teacher-pupil-control mechanism with the goal of education as its norm. The important question again is what should be the highest goal.

When defects occur the teacher as the higher control level should take correcting steps, e.g. when the temperature of a room is thermostatically controlled and the temperature of the room is too high to be comfortable because of too high a setting of the thermostat, the only correct way of adjusting the system is to change the setting of the regulator. If one should try to change the system by cooling the heating element, just the opposite reaction will be attained because the system will react vigorously by increasing the heat output of the element. The same applies to the receptor i.e. thermometer, if it is cooled

down, the control system will react by increasing heat output, if the thermometer is heated, the heating element will be switched off as a result of "misleading" information from the thermometer concerning the room temperature. This example serves the purpose of illustrating the importance of changing the norm values of the *control centre* rather than evoking resistance from the motor side. In education the individual as a whole i.e. all levels of control, should be considered. Standard values, norms, control and control integration into higher order goals or purposes are all important.

Control is necessary for the maintenance of "normal" structure and function. The order of "normal" structure and function is determined by certain norms or value standards. In any entity coordination and cooperation are essential for its survival as a unit. This is very important in any political structure. Unity is one of the main functional ideals of a political system. The integrated and coordinating unit is much more stable against threats from inside as well as outside because it can resist and survive. Misuse of these principles in a dictatorship always leads to disintegration because it usually eliminates the responsibility of the lower control levels or underestimates them. In any well organized state all control levels should operate in their own domain but not as autonomous units. All these different levels should be integrated into a whole of a higher order. In this way *Ex unitate vires* could really become true. In a totalitarian state there is no complete circuit of information, real negative feedback is not possible.

The important question again is, what should be the goal or purpose of the highest order. All standards, norms, values and laws should take into consideration the different goals at each level of control. Is this goal the survival of the political system of the nation as such and its resistance to threats?

The crisis of modern society

Man in this modern society is threatened by tremendous crises. The threat of world war and even total extinction, over-popula-

tion, under-, mal- and overnutrition, environmental pollution, economic instability, heart disease, traffic accidents, violence, suicide, drug addiction, alcoholism, especially in western countries, enslavement by a technocratic society, many seemingly insoluble problems such as the problem of respect for life, abortion, euthanasia, experiments with humans, the place of moral and ethical values etc., all loom over him.

Science and technology are assumed to be amoral. No ethical or moral values operate in the field of scientific work. Science is autonomous because human thinking is autonomous. In medical science where moral and ethical codes have dictated a code of behaviour or action for many years tremendous shocks have come and uncertainty over the question of moral values and the fundamental basis upon which these values should be founded is now reaching its climax. Tradition, scientific knowledge, common sense, pain, suffering, human dignity, respect for life etc. all seem to be too unstable to use as norms or standards in a control system. Many authors agree that a new order or re-evaluation of older values is very urgent.

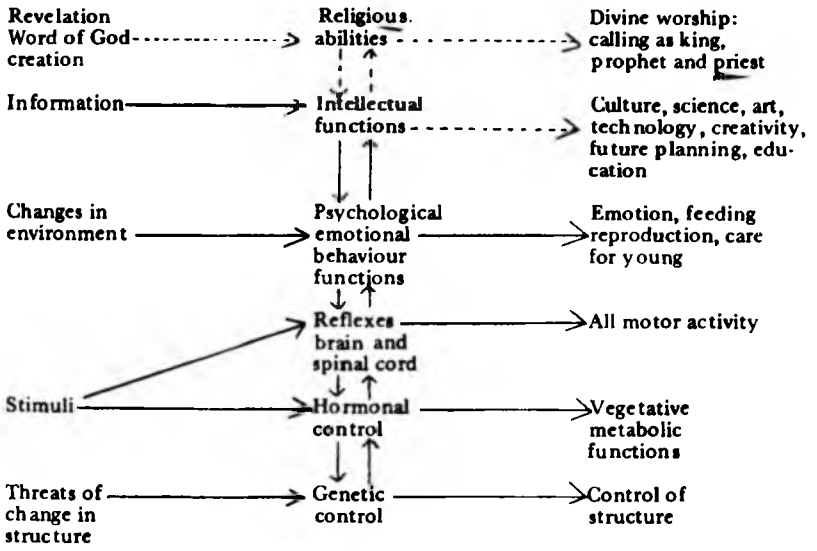
The biological pre-assumption that man has evolved from primitive forms of life or even from the lifeless nature, together with the generally accepted physiological dogma that man is not more than a complex machine, has a tremendous impact upon the modern way of thinking.

Fundamental considerations are the following: The Creator of the cosmos should be honoured as the source of all living and non-living things. He is the living God. He possesses the power to create matter and to create life from non-living matter. He maintains and supports all living and non-living things by means of His power of Providence. By sin the relation between God and man has been drastically disturbed. By the grace of God Christ was sent to earth to restore the relation. The ultimate purpose of the creation of matter and the highest goal for man is the glory of God. Nothing in creation can be autonomous because God is the sovereign ruler. Thus, neither man nor any intelligent force, science or technology can be regarded as independently self-sufficient because all things are related to their origin the Creator.

One effect of sin is disturbed relations and these can cause the illusion of independence or autonomy, this is one of the many defects of natural control mechanisms and integrated control systems. This can be visualized as an uncoupling of higher and lower control levels. The effect is that the uncoupled lower part of the control system will perform as an autonomous system but it will act in a robot-like or caricaturish manner because the higher meaning or purpose of the higher control level is lost. This is what happens if man loses his relation with God. The highest level of control is now his own intellectual abilities. He has now only two options left, i.e. to feed his religious control functions with his belief in culture, science and technology or to create his own religion based on his intellectual abilities.

The different control mechanisms and interrelations can be presented in the following oversimplified scheme in Figure 2.

Figure 2



Each level of control functions according to its own characteristics. In an analytical sense, thus, the genetic control will maintain the structure of the body, hormonal control the metabolic adaptation in reaction to stimuli from the internal and outside environments and the reflexes, motor activity, etc.

As was mentioned earlier, the control on each level has its own basic functions but it also influences the other levels of control. On the other hand the higher levels have a very wide range of modulating influence on the lower levels. Each level has its own goal or purpose. The higher levels integrate the functions of lower levels so that a higher purpose could be served or a higher goal striven for. Uncoupling of any levels of control will "free" them from the higher levels. An animal without intellectual control behaves according to its behaviour control and instinct. Very strong influences over many functions of the body are under the control of the brain cortex. The older physiological divisions between so-called voluntary, involuntary, or limbic behaviour, autonomic and endocrine control are no longer recognized, e.g. it is now well known that a person can learn to control so-called involuntary functions such as heart frequency. The control of the brain is far reaching and no part of the body is really autonomous, or independent. The brain can influence the most basic biological metabolic functions drastically by means of its control over the autonomic and endocrine control systems. Normal man always functions as an integrated unity. Whatever he does, thinks or plans most of his control levels are usually involved. As an integrated unity man is the best equipped to fulfill his purpose in nature i.e. to control, create, plan, etc. His highest purpose can only be served as an integrated unity. Analytical procedures always disturb the interaction between control systems and because they uncouple the lower from higher levels they will eliminate integration as well.

If the religious control is excluded most of the human activity is only directed towards survival. It is merely a matter of viewing the function of a control mechanism from its purposeful or goalseeking aspect. E.g. in some animal colonies something

like unselfishness of the individual is observed such as laborious care of the young or suicide during overpopulation. However, viewed from a higher control level than the survival of the individual, these actions are only a result of the control of the survival of the colony, species or race etc. Thus a higher control level than the individual may secure the survival of the group or nation.

Is most of our present day culture, science and art not merely becoming a characteristic function of a control system or even directed towards this goal namely the survival and resistance, of any or all of the individual, group, culture, nation, human race biosphere, nature and our planet? Our efforts to obtain law and order, elimination of aggression, disease, pain, accidents, art, conservation of nature, resistance to change, to foreign ideologies become nothing more than negative feedback control for survival of the individual, group, culture, nation, etc. A symptom of this is the many ineffective efforts to curb problems in society: pollution, drug abuse, alcoholism, violence, aggression, war, technocratic development, etc.

Freedom is not obtained by decoupling of the levels of control or creating more powerful levels of control, this only leads to slavery. The only solution is to restore full integration on all levels of control, including the religious level. The real meaning of creativity, future planning, love, imagination, language etc. can be restored, because in Christ the relationship with God is restored. The highest purpose of all human effort is then clear, namely the glory of God and the well-being of one's neighbour.

If the purpose of any intellectual or behaviour activity is survival, or maintenance of any specific order, science for the sake of science or art for the sake of art, it is uncoupled from its religious control level and then it becomes no more than negative feedback control for survival on that level. Culture, futurology, medical research and organising of society are then nothing more than security measures for, or creation of, a high quality of life for the survival of a specific kind of life. The illusion of eternal life on earth, a painless world and the creation of a heaven on

earth may then become goals. From this circle of negative feedback, action and reaction and seemingly unending oscillations, threats, resistance, dynamic equilibrium, disturbance of power balance, revolt and anti-revolution, aggression and peace, it is impossible to escape by means of intellectual abilities as highest control. Most intellectual systems of thought which intend to free man from his dilemma clearly show this process of circular thought because they are uncoupled from the higher religious control level and thus become a robot or caricaturish performance. This is quite obvious because they only depend upon the natural processes of brain functioning which cannot perform in any other way than that determined by genetic, hormonal, behaviour, psychological and intellectual control levels. They will always remain subject to all the limitations and above-mentioned defects of control mechanisms. No known control system can operate in a perfect way. This is inherent in the system. Oscillations are one of the obvious symptoms. Man is always moving from one extreme to another in his uncoupled, autonomous way of thinking: history can prove this, for instance in the movement from absolute domination of thought by the church to secularism. Oscillations can't be avoided because a natural control system is dependent upon the residual deviation before correcting reactions are programmed. Over- and underreaction, positive feedback, disintegration of control levels all occur very often in human thinking. Our present day lack of norms or standards is causing total chaos in our intellectual control systems.

Jesus Christ did not resist crucifixion. He regained our relation with God. He broke through the natural earthly circuits of resistance. As highest level of control He can change our thinking by enlightening our life. By belief in Him and His power over the whole creation all our control levels can be integrated to serve a higher purpose, namely the glory of God and well being of our neighbour. New meaning is then given to our intellectual, emotional, behaviour reflex, hormonal and genetic control. Man is given purpose in leading a life of gratitude. This means that eternal purpose is given to one's life, in the calling to live as king, prophet and priest in the Kingdom of God. By this is implied not

only a so-called spiritual change but also a fundamental bodily, metabolic material effect because man is a unity as suggested in Figure 2. This also means liberation from the slavery of negative feedback circuits of thought because life has a higher purpose and death is no longer a terminus but a transit station. Slavery to any intellectual system or technology will not be possible. The unity with Christ as head of his congregation, his body, implies that all levels of control will be integrated into this eternal unity here and now. 1 Cor. 12:12-31.

This new freedom implies dynamic activity of the highest order. A dynamic balance between freedom and responsibility is created. Human intellectual activity is now driven not only by resistance and survival control but by the urge to serve the King of all kings to attain control over nature, to serve one's neighbour in a spirit and mood of deep gratitude for one's redemption by Christ and the liberation from slavery. This can free one's intellectual functions from any scientific, traditional, national or political dogma or absolutisms. This can supply one with a true basis for moral and ethical standards in scientific activity. Real human dignity and respect for life as a gift of the living God is thus restored. This freedom is of the utmost importance in physiological research and education.

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