

# Control Theory Approach of Medical Therapy Involving Homeostatic Equilibrium Restoration

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## Abstract

*Control theory approach of medical processes is a very useful instrument for both medical and engineering studies. It creates a global vision of how medical therapy works for restoration of health. Medical therapy is based on reductionist methods (a classical deterministic approach) and holistic methods (closer to natural homeostatic equilibrium restoration and noninvasive). The act of medical therapy is being seen as an adapting system, while the human body is being seen as an adaptive system.*

**Key words:** *control theory, medical systems, systems theory, adaptive system, adapting system, homeostasis, set point, effector, control center, reductionism, holism.*

## Introduction

Systematization of anatomy components and medical activities are a necessity in addressing fundamental methods of therapy. A completely new approach can result from systems theory and can lead to atypical, completely new therapeutic algorithms, which could not be discovered through a purely medical approach. The control theory approach of medical therapy is useful both for medical doctors and engineers. This study is an instrument for medical engineering and can be useful in medical therapy phenomena understanding.

## A Control Theory Approach of the Human Body's Homeostatic Control System

In Figure 1, it is shown a control theory approach presentation of the homeostatic control (coined by Cannon in 1926 [1]). It notes the existence of all the elements that constitute a system. The internal process is monitored by sensors and is subject to interference. Information taken from the sensors are continuously compared with reference values (which are, in fact, reference intervals), and if there are differences then stimuli arises. They get through afferent pathways to the central nervous system - which is the controller.

The control center also receives filtered information related to some disturbances. This information correlated with stimuli that arrive as a result of the comparison process leads to decisions generated by the CNS (Central Nervous System). Decisions concern not only the effectors, but also the possibility to activate feed forward paths to prepare the body to initiate other processes that must accompany a complex task for which the memory of a behavioral

pattern exists (e.g. cycling - control center notifies intention to start pedaling and prepares processes specific for intense effort over a long period).

The command is transmitted through efferent pathways to the effectors. They act on the process as long as the stimuli exist, until the information received from the sensors is within the range of the reference values (when using negative feedback).

Every system in the body contributes to homeostasis of other systems and of the entire human body. An interruption in one system's self-regulation process has consequences for several systems of the body.

When we refer to homeostasis we mean exclusively human homeostasis (a particular case of biological homeostasis). Starting from the definition of homeostasis as being the ability or tendency of an organism or cell to maintain internal equilibrium by adjusting its physiological processes, we can see what is in systemically. "The ability or tendency" actually means a set of rules by which the body can return to a state of equilibrium. [2] Considering all the above we can conclude that:

**Homeostasis = normal state of dynamic equilibrium of internal processes variables of the human body**

Homeostatic adjustment process is nothing more than running control algorithms in systems that arise around regulated processes. The result of applying the algorithm represents all decisions to be taken between the emergence and disappearance of stimuli. Stimulus occurs as a result of differences between input data provided by sensors connected to process incoming through afferent channels (nervous or circulatory system) and reference values stored in the genetic code or the nervous system. Reference database is in part inherited (the evolution), partly built from the life experience of the body.

**Stimulus = information error (a deviation from the set point or getting out of the reference range)**

The first relationship that we can deduce is the relationship between homeostatic regulation and internal stimuli:

**Homeostatic regulation process state = f (stimuli)** (1)

We also know that the stimuli are dependent on information provided by the human body sensors, internal process variables to be adjusted and the reference contained in the structure of the body:

**Stimulus = f (sensor information, reference values)** (2)

where:

**Sensor's information = f (process variables)** (3)

The results of the homeostatic regulation are commands generated by the central nervous system which are transmitted through efferent pathways to the effectors associated with the controlled process (fig. 1). They act on process variables until the stimuli disappear.

**CNS commands = f (homeostatic adjustment process, stimuli, disturbance)** (4)

(CNS = central nervous system)

The result of homeostatic regulation is the correct functional parameters of the adjusted process variables. It can be said that the cancellation of process variables deviation is directly dependent of the effectors (actuators) action:

**Cancellation of the deviation variables = f (effectors action)** (5)

where:

**Effectors action = f (CNS commands)** (6)

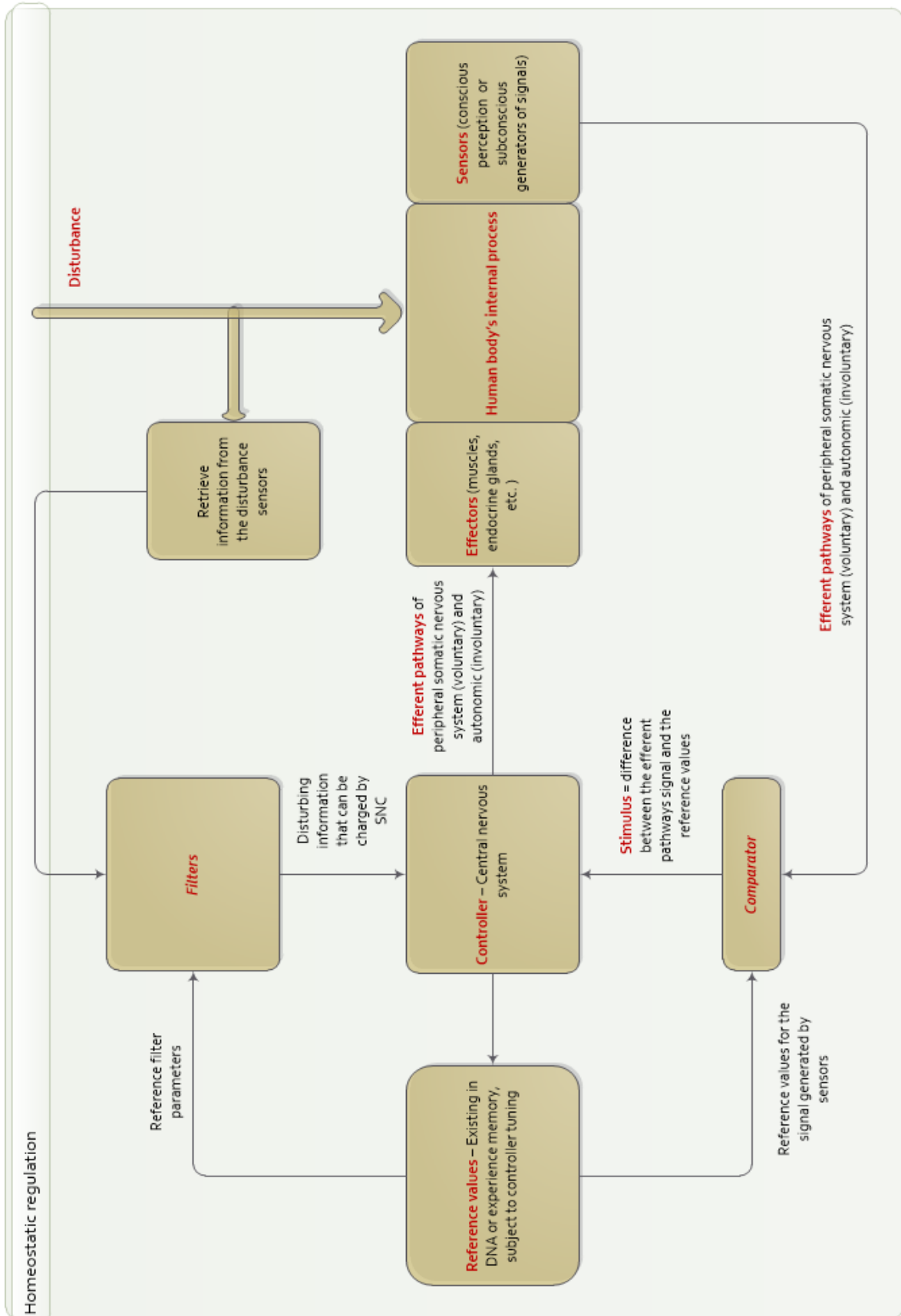


Fig. 1. A control theory approach of the homeostatic control system

We can now see all the elements that contribute to achieving homeostatic balance. The purpose of regulation is the cancellation of the adjusted process variables deviations, and taking into account relations (1), (2), (3), (4), (5) and (6) we deduce the following dependence:

**Cancellation of variables deviations = f (homeostatic adjustment process, reference values, process variables, disturbance)** (7)

There are situations where the reference values are changed by the CNS in order to alter the normal homeostatic control to limit transient situations - such as protecting the body against bacterial or viral infection. Changes are always reflected in the body condition, therefore reference values may become uncorrelated to the physical condition of the body.

**Set points = f (SNC decisions, body condition)** (8)

Thus the whole process of homeostatic regulation is depending on the amplitude of the process variables, on the reference database of the human body (which is also subject to changes in the CNS), on the control algorithm (homeostasis) and on disturbance (which acts both on the controlled process and the homeostatic control system components).

When does the homeostatic control system intervene? When process variables are deviations from reference values or ranges of the body. We can assume two scenarios:

**Scenario I - consider regulating homeostatic system components fully functional.**

In this case we can talk about two major sources of imbalance, namely:

1. Disturbances - by which we mean both environmental conditions and the aggression of microorganisms.
2. Trauma - in any manner that cause damages of the organs involved in controlled processes.

In both cases homeostatic control system intervenes to restore the body to equilibrium. The system boundaries occurs when disturbances or trauma are extreme, in this case, a state of imbalance become permanent and can lead to death.

Scenario I is the normal state of operation of homeostatic control system. In this context, medicine interferes with allopathic drugs (for major disturbances) or surgical procedures (in major trauma) to assist in the establishment of equilibrium.

**Scenario II - consider dysfunctional homeostatic control system components or suffering from organic changes.**

In this case, the homeostatic control system cannot bring the state of equilibrium or it may interfere with the process even when it is not needed. Scenario II is generally temporary and is corrected by invasive methods in case of organic modifications. Problems in scenario II are leading to major functional disorders even in the absence of disturbance or trauma.

What problems can lead to scenario II? We will try to identify these problems and their consequences:

1. Organic or functional dysregulation of sensors => leads to erroneous measurement process of adjusted variables values => appearance of artificial stimuli, uncorrelated with deviations.
2. Organic or functional dysregulation of comparators => leads to erroneous detection of errors related to afferent pathways signals => appearance of artificial stimuli, uncorrelated with deviations.
3. Reference Database altered => leads to appearance of artificial stimuli, uncorrelated with deviations.

- The alteration may be permanent - in this case we are dealing, probably, with a harmful genetic inheritance - this generates genetically inherited diseases that are a permanent menace (here an important role is played by prophylaxis).
  - The alteration may be temporary - then we can talk about temporary correction of how stimuli are treated.
4. Organic or functional dysregulation of control center => leads to decisions that are not related to stimuli or does not respect the rules of regulation (homeostasis) => major dysfunctions occur in the regulated processes, the correction in this case being almost impossible.
  5. Organic or functional dysregulation of effectors => commands from the CNS, even correct, cannot change appropriate the adjusted process variables, correction based on deviation is no longer respected.
  6. Organic or functional dysregulation of afferent pathways (nerves or parts of the circulatory system) => information from the sensors gets corrupted or does not reach the control center – the feedback loop disappears.
  7. Organic or functional dysregulation of efferent pathways (nerves or parts of the circulatory system) => leads to distorted commands or the inability to reach the effectors - the process cannot be adjusted.
  8. Alteration of control algorithm (homeostasis) => this affects the whole regulation system - generally this dysfunction is associated with altered control center.

When it comes to organic disorders invasive therapeutic methods are used being either radical - such as surgical methods, laparoscopic, or less invasive - endoscopic. Most problems that may occur in scenario II rise to artificial stimuli, uncorrelated with the deviations of controlled process variables. In these situations medicine appeals to allopathic treatment that is temporarily blocking control center receptors that are connected to the related pathways. Known are treatments that block beta receptors and / or alpha (Beta / Alpha-adrenolytic) in the sense of ignoring the presence of adrenaline (norepinephrine) - this avoids control center commands resulted from false stimulus.

A case apart is total dysfunction of the control center (CNS = central nervous system). It holds the control algorithm - homeostasis. In this situation is altered homeostatic regulation principle itself - functional alteration being the change of the control algorithm. The causes of these disorders are often disturbances as CNS stress, fatigue, and negative feelings - especially traumatic reactions. This is manifested by changing the values of variables in the control center (e.g. quantitative reduction of hormones that can have dramatic effects – such as serotonin or endorphins). When these situations occur we can change these values using allopathic/homeopathic medicines, psychotherapy to identify and remove stress.

## **A Control Theory Approach of Medical Therapy Based on Reductionist and Holistic Methods**

Many of the methods applied in medicine are a result of a reductionist approach to therapy, not infrequently ignoring the primary reason of the dysfunction. For example - modified level of serotonin, which is a neurotransmitter, is an intermediate effect in causing neurovegetative disorders - the primary reason being the stress and the secondary being the occurrence of false stimuli. Changing levels of serotonin occurs much later in the list of effects, which is responsible (among other things) for the state of mood we perceive. Another primary reason may be the existence of a small number of serotonin receptors – this being an organic disease.

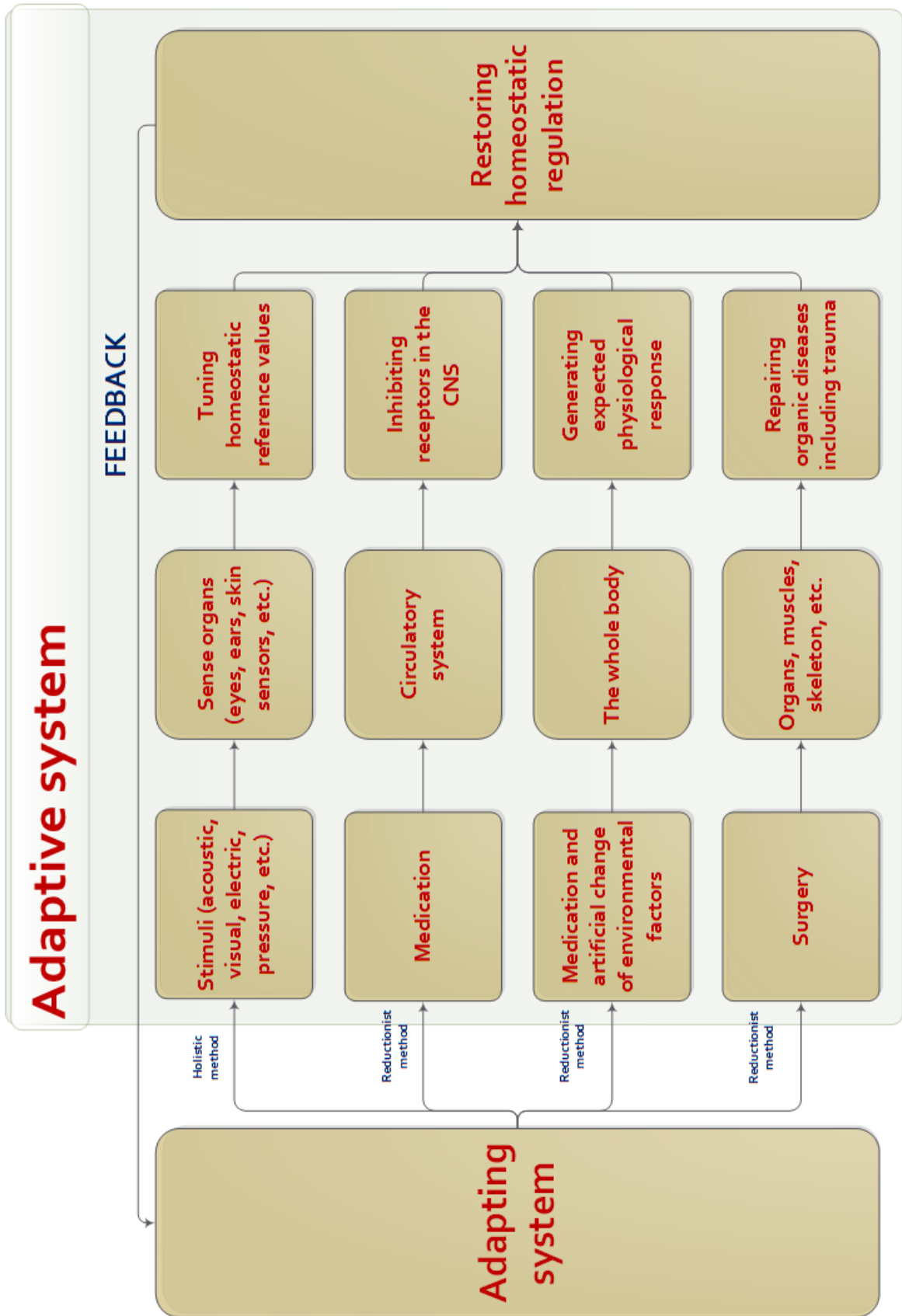


Fig. 2. Influence of homeostatic control system (adaptive system), using an adapting system with physiological influence capability.

Reductionist approach assumes that if a body is dysfunctional, it is the result of other disturbances at sub organic level. This theory is applicable and gives positive results when we deal with organic diseases. If functional problems occur, reductionist theory is no longer as viable.

Another approach is the holistic therapy. **Holism** (coined by Jan Smuts in 1926) (from the Greek holos = whole) is a conceptual claiming irreducibility of the whole to the sum of the parts, meaning that some of the whole features cannot be explained in terms of properties and relations of the components. [3]

**Reductionism** is often viewed as the opposite to holism (or emergentism) (Jones, Richard H., 2013). Reductionism in science says that a complex system can be explained by reduction to its fundamental parts. [4]

Scientific holism claims that the behavior of the system cannot be perfectly predicted, regardless of how much data is available. Natural systems can produce surprising behavior, unexpected. Only that these unexpected behaviors are considered by some scientists to be rare, and thus leaving the reductionist deterministic approach as the predominant. (S. Wolfram, 1984) [5]

Complexity theory (M. Waldrop, 1993) [6] - also called the "science of complexity", is a contemporary heir of holistically thinking systems. It comprises both computational and holistic approach, related with the purpose of understanding complex adaptive systems.

A case of unexpected behavior in terms of computational approach is the neurovegetative dystonia. Here we are dealing with a healthy body, whose components are healthy, there is a notable absence of disturbances and still have unexpected behavior by excess secretion of adrenaline in the body. Reductionist approach in this case is useless. Sometimes we deal with conscious thinking or perceptions which lead to somatic changes (so called psychosomatic relations).

How a person's mental state strongly influences the somatic nervous system, we conclude that changing mental status changes generate somatic nervous system. Studies on the functional pathology (such as those of Gustav von Bergmann who founded **psychosomatic medicine**) were observed several neurological disorders conditioned. [7] Examples of such disorders are high blood pressure, tachycardia, ventricular ulcer, duodenal ulcer, etc.

Much functional pathology of specific disorders is related to the mental state of a person. Conditional neurological changes are usually the result of external disturbances, especially stress - as evidenced in (8). Restoring psychological equilibrium and regaining the ability to relax lead to the reduction or disappearance of neurovegetative disorders. This is achieved through psychotherapy, self-education or by stimulating the senses of any nature by empirical algorithms or art.

**With access to mood, homeostatic control system is an adaptive system that influence mood, thus becoming an adaptive system.**

The adapting system can consist of various methods (fig. 2.). Holistic methods are basically based on stimuli of any kind the human body is sensitive for. This stimuli include verbal communication such as psychotherapy or suggestions. The major advantages of this methods are:

- The lowest grade of invasiveness
- Natural tuning of the homeostatic processes by changing the reference values
- The most efficient methods for compensating psychological stress generated dysregulation

The dependency can be write as:

**Homeostatic reference values restoration = f (stimuli generated by holistic methods)** (9)

Reductionist methods can vary from medication to surgery. Surgery (the last resort - implying invasive procedures) is usually used when we deal with organic changes of homeostatic regulation components (especially surgery). Medication usually blocks false stimuli on afferent pathways by inhibiting receptors in the central nervous system.

**Homeostatic components organic restoration = f (surgery – reductionist methods)** (10)

**Interrupting dysfunctional homeostatic regulation process = f (medication – reductionist methods)** (11)

Changing the environmental parameters such temperature or humidity leads to inhibition of stimuli generated by sensors. This is applicable to abnormal sensations generated by stimuli that are out of the normal range. For example we feel cold, but the ambient temperature is in normal ranges and the body is physically healthy, so we increase the external temperature in order to inhibit the stimuli that generates the cold sensation.

**Inducing expected homeostatic regulation results = f (artificial change of environmental factors and medication – reductionist methods)** (12)

## Conclusion

Engineers can develop medical devices using a systemic approach. Because of the major implications of engineering in medicine, modernization of medical service became possible due to significant increase of the success rate in the therapeutic process and reducing the invasiveness with major impact in reducing trauma and recovery time for patients. A system theory approach in medical engineering is thus mandatory.

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## Abordare bazată pe teoria controlului a terapiei medicale ce duce la restaurarea echilibrului homeostatic

### Rezumat

*Abordarea bazată pe teoria controlului a proceselor medicale este un instrument foarte util deopotrivă pentru studiile medicale și de inginerie. Se creează o viziune globală a modului în care terapia medicală acționează pentru restabilirea sănătății. Terapia medicală se bazează pe metode reducționiste (o abordare deterministă clasică) și metode holistice (mai aproape de modul natural de restaurare a echilibrului homeostatic și, în același timp, neinvazive). Actul terapiei medicale este văzut ca un sistem de adaptare, în timp ce corpul uman este văzut ca un sistem adaptiv.*