Biofeedback and the Behavioral Treatment of Disorders of Disregulation

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This paper reviews biofeedback research from the perspective of cybernetic/feedback theory and applies the theory to the behavioral treatment of psychosomatic disorders. The concept of disregulation is used to elucidate how environmental factors can modulate the central nervous system and effect homeostatic, self-regulatory control of peripheral organs. When feedback from peripheral organs is disrupted, it is hypothesized that disregulation occurs, leading to physiological instability and functional disease. Within this framework, biofeedback provides a new feedback loop that can help individuals regain physiological self-control. Basic research using biofeedback to enhance self-regulation of cardiovascular responses is reviewed. The use of biofeedback in the behavioral treatment of disorders such as tension and migraine headache, hypertension, and epilepsy are selectively reviewed and critically evaluated. The need to consider feedback mechanisms in behavioral and biomedical approaches to treatment is highlighted. Predictions regarding the potential inadvertent perpetuation of disregulation and disease through inappropriate biomedical intervention is also considered.

Corrective information, termed negative feedback in cybernetic theory [1], is fundamental to behavior that is self-regulatory. Unfortunately, the concept of feedback is so obvious that it is often overlooked by health professionals and patients alike. Everyone knows that they must have external visual feedback and internal kinesthetic and proprioceptive feedback to tie a knot or to serve a tennis ball. In neurophysiological terms, it can be said that the brain requires feedback of what it is doing and of its surroundings in order to appropriately regulate itself and its body [2,3].

The product of twentieth century biomedical technology, biofeedback is a new form of physiological information. With modern electronics it is now possible to accurately monitor a variety of physiological processes and convert these signals into novel forms of visual or auditory information. This information can be consciously perceived and processed by the brain, and thereby self-regulated by the brain.

This development has stimulated extensive research on the voluntary control of neural, visceral, and skeletal responses [4], and the application of biofeedback to the behavioral treatment of psychophysiological disorders [5]. Although I emphasize a neurophysiological interpretation of biofeedback and its application to the treatment of psychosomatic or functional [6] disorders, this approach is recent in origin and does not reflect the historical development of biofeedback [7].

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The early research was derived primarily from learning theory, emphasizing concepts and methods of instrumental [8] or operant [9] conditioning. However, investigators who adopted a feedback perspective tended to stress the role of information in self-regulation, whereas researchers who took a learning approach tended to stress the role of incentives or motivation in the development and maintenance of self-control [10–12]. As will be emphasized in this paper, information and incentives are both important to the clinical application of biofeedback procedures, and they can be understood in neurophysiological terms.

Yogis and meditators have long claimed unusual powers of voluntary control over their physiology and consciousness, but until recently these claims were dismissed by the scientific community. Since the previous scientific theories or paradigms could not explain such claims, the claims were dismissed as being inaccurate or fraudulent [13]. Not only did previous paradigms in medicine disallow the voluntary control of visceral and glandular responses, but so did the prevailing learning paradigms in psychology. However, stimulated by the development of biofeedback, coupled with advances in neurophysiology, new paradigms have evolved which seek to explain and extend these observations [e.g., 2,3]. In the process, this new information is revisiting our theories of health and illness, and therefore the means by which we treat and prevent disease.

Unfortunately, the initial fervor for biofeedback was so strong that it became almost fanatical. At times the popular press was filled with uncritical enthusiasm for almost any speculation about biofeedback as therapy. The electronics industry took advantage of this interest and exploited biofeedback in both the medical and lay markets. As a result, today there are at one extreme those who argue that biofeedback can enable humans to control any aspect of their biology at will; at the other extreme, a growing number now dismiss biofeedback as a useless gimmick. The thesis of this article is that neither of these extremes is appropriate. Current research on biofeedback not only expands our understanding of human self-regulation and its applications to medicine, but also helps us recognize its limitations [14].

**DISREGULATION: A PSYCHOBIOLOGICAL MODEL OF PSYCHOSOMATIC DISORDERS**

In order to appreciate the potential and limitations of biofeedback in the treatment of psychosomatic disorders, it is essential to view biofeedback within a biobehavioral perspective. The following is a brief introduction to the psychobiology of psychosomatic disorders emphasizing the concepts of feedback [1] and disregulation [2,3].

The concept of feedback is central to an understanding of health and disease. As originally posited by the French physiologist Claude Bernard and elaborated by Walter Cannon in his classic volume, *The Wisdom of the Body* [15], there is a biological necessity to maintain physiological variables within certain limits in order to survive. This is accomplished by homeostasis, a process requiring an intact nervous system. Homeostasis, therefore, is an internal negative feedback mechanism, devoted to the maintenance of the internal organs. In cybernetic terms [1], it is negative in the sense that the feedback acts to dampen overresponding in a corrective, stabilizing manner. In this sense the brain can be viewed as acting like a biological “health care” system [3].

It follows that if the negative feedback circuit is altered or made ineffective, normal self-regulation will not occur, and the system will become unstable (disordered). I have called this instability disregulation [2,3] which is similar to Miller and Dwarkin’s [16] concept of anti-homeostasis.
In its simplest form, the model (see Fig. 1) is as follows: When the environment (Stage 1) places demands on a person, the brain (Stage 2) performs the necessary biobehavioral regulations to meet the specific demands. Depending upon the nature of these environmental stresses, certain bodily systems (Stage 3) will be activated, while others may simultaneously be inhibited. However, if this is continued to the point of placing excessive strain on a given organ, the negative feedback loop (Stage 4) of the homeostatic mechanism will normally be accentuated, forcing the brain to change its course of action. Sometimes the feedback can result in the subjective experience of pain.

For example, if a person is overactive and eating on the run, the stomach may fail to function properly. As a result, the stomach may generate sufficient feedback to the brain to be experienced by the person as a stomach ache. From a health care point of view, this corrective signal should serve the important negative feedback function of causing the brain to change its regulation in specific ways, such as leading the person to slow down and allow digestion to occur normally. Pain can serve a second function in that it can "teach" the brain what it can and cannot do if the stomach is to work properly. The adaptive brain is one that can learn through its mistakes. It should learn to anticipate the needs of its organs for the sake of the organs' health.

However, the brain may fail to regulate itself effectively to meet the stomach's needs. The reasons for this can be quite varied. As shown in Fig. 1, there are four major stages where disregulation can occur.

**FIG. 1.** Highly simplified block diagram depicting (1) environmental demands influencing via sensory inputs (not shown), (2) the brain's regulation of its (3) peripheral organs, and (4) negative feedback from the periphery back to the brain. Breakdowns in homeostasis and disregulation can be initiated at each of these stages. Biofeedback (Stage 5) is a parallel feedback loop to Stage 4, detecting the activity of the peripheral organ (Stage 3) and converting it into environmental information (Stage 1) that can be used by the brain (Stage 2) to increase self-regulation (from [2]).
**Stage 1: Environmental Demands**

The stimuli from the external environment may be so demanding that the brain (Stage 2) is forced to ignore the negative feedback (Stage 4) generated by the stomach (Stage 3). This is the classic case of the person placed in unavoidable stress who must continue to act in certain ways despite negative feedback to the contrary. Many previous theories of psychosomatic disorders have emphasized this factor.

**Stage 2: CNS Information Processing**

The brain may be so programmed (initially through genetics and/or subsequently through culture and learning) to respond inappropriately to the stimuli in the external environment. This is what we in psychological or behavioral terms refer to as personality or life style. Thus, although feedback from the abused organ may be present, the person's brain may fail to react to it appropriately, as in denial or repression.

**Stage 3: Peripheral Organ**

The organ may be hyper or hyporeactive to the neural or hormonal stimulation coming from the brain. This is the literal translation of what has sometimes been called the "weak organ" theory of psychosomatic disorders. It can explain why, in response to the same environmental stress, people differ in the organ that ultimately becomes dysfunctional. From this perspective, it is possible that the brain cannot regulate itself to compensate for the altered feedback it is receiving from the organ. In the case of a diseased organ, it may find itself no longer capable of modifying the functioning of the organ.

**Stage 4: Negative Feedback**

Finally, the negative feedback derived from the organ may be inappropriate. In other words, it is possible for the negative feedback itself to become less effective or even inactivated. An extreme example of this condition can be seen in persons born without the normal pain response system [17]. These individuals are constantly in danger of severely injuring themselves, for they lack the protective mechanisms for detecting and coping with injury.

Although the etiology of disregulation can occur at any of these four stages, the general consequence of disregulation is the same in each case. By not responding appropriately to negative feedback (Stage 4) the brain (Stage 2) fails to maintain stable regulation of the organ in question (Stage 3) and disregulation (with its accompanying instability) emerges.

Not only can disregulation occur at each of the four stages in the system, but it is possible for problems to occur simultaneously at multiple stages. In the extreme case, if a person was (1) exposed to demanding stimulation in his environment, requiring continued adaptation (Stage 1), and (2) his brain processed the sensory information and reacted inappropriately due to genetic and/or learning factors (Stage 2), and (3) the peripheral organ itself reacted inappropriately due to genetic and/or maturational factors (Stage 3), and (4) the feedback mechanism derived from this organ was also ineffective (Stage 4), this combination would dramatically increase the likelihood that such a person would develop a specific stress-linked disorder. Since the brain and body are composed of multiple systems that must be coordinated in an integrated fashion, it becomes necessary to examine each of the components and then consider how they combine so as to produce the final outcome/disease.
This holistic perspective to psychosomatic disorders illustrates how the functioning of the system as a whole (Stages 2–4) requires the adaptive coordination of all of its components in response to a variety of environmental demands (Stage 1). By emphasizing the concept of feedback, the disregulation model provides a framework for viewing biofeedback as the creation of a new feedback loop (Stage 5) to potentially augment homeostasis/self-regulation [2]. By taking a neurophysiological, multiprocess perspective, the disregulation model can help delineate the conditions under which biofeedback will or will not be effective as a clinical tool.

BIOFEEDBACK AND PHYSIOLOGICAL SELF-REGULATION: BASIC RESEARCH

Hundreds of basic research studies have now been published, demonstrating enhanced physiological control with feedback and reward. The list of responses brought under self-control includes systolic and diastolic blood pressure, heart rate, blood flow, sweat gland activity, skin temperature, body temperature, respiratory functions, genital responses, stomach motility, skeletal muscle control (including single motor units), and various changes in the electrical activity of the brain. Many of these studies are reprinted in a set of Biofeedback and Self-Control volumes [e.g., 18–23] and are critically evaluated elsewhere [4].

A useful example of basic biofeedback research concerns blood pressure self-regulation in normotensive subjects. It is now well established that normal subjects can learn to regulate their systolic and diastolic blood pressure depending upon the nature of the feedback, instructions, and rewards used. If subjects are given simple binary (tones or lights, on-off/yes-no) feedback for relative increases or decreases in systolic pressure at each beat of the heart, are given minimal instructions about what they are to do (they are not told what specific response they are to control, nor are they told in what direction their physiology is to change), and rewards in the form of slides (in these early studies, male subjects saw pictures from Playboy magazines), subjects can learn in 25 one-minute trials to increase or decrease voluntarily their systolic pressure without producing similar changes in heart rate [24,25]. Conversely, if the feedback and reward is provided for increases or decreases in heart rate, and minimal instructions are again used, subjects rapidly learn to increase or decrease their heart rate without similarly changing their systolic pressure [26]. These data illustrate how biofeedback procedures can enable subjects to learn to control specific responses associated with the feedback in the absence of specific organ instructions. In more neurophysiological terms, if the brain is required to process the external feedback without any “preconceived notions,” it readily learns to regulate those specific neural processes required to activate the periphery and thereby control the feedback.

Subjects can learn to regulate two or more responses simultaneously if feedback and reward is given for the desired pattern of responses. For example, if subjects are given binary feedback and slide rewards only when their systolic blood pressure and heart rate simultaneously increase ($BP_{up}$HR$_{up}$) or simultaneously decrease ($BP_{down}$HR$_{down}$) subjects now learn to regulate both responses [27]. Interestingly, teaching subjects to control patterns of responses uncovers biological linkages and constraints between systems not readily observed when controlling the individual functions alone [3,11,14]. For example, when subjects are taught to lower both their systolic pressure and heart rate simultaneously, they tend to show more rapid learning, produce somewhat larger changes, and experience more of the subjective
concomitants of relaxation than when they are given feedback for either function alone [27]. When subjects are given pattern biofeedback for making these responses go in opposite directions (BP↑↑HR↓↓ or BP↓↓ HR↑↑), regulation of the two responses is attenuated. These observations are important because they highlight the concept of physiological patterning in both basic research and clinical treatment [3,11,14] and emphasize natural physiological constraints that must limit the degree of neural control possible.

In all of the above-mentioned studies, subjects were given minimal instructions about the task. When subjects are specifically instructed to control their heart rate or blood pressure, however, the subject may demonstrate physiological control even in the absence of any feedback [28,29]. However, it is a mistake to conclude that instructional control is identical to regulation gained through biofeedback! Whereas single system biofeedback leads to learned specificity, instructions often lead to more complex patterns of responses. Hence, the verbal instruction to control blood pressure leads to control of heart rate as well, whereas single system biofeedback for blood pressure with minimal instructions can lead to blood pressure control in the absence of heart rate control. It follows that the precise nature of the biofeedback and the specific instructions used both contribute to the final pattern of responses that the subject will learn to regulate. It should not be surprising to learn that instructions differentially influence physiology. The average adult brain can draw on a variety of neural strategies in its conscious repertoire to control the feedback. Depending upon the specific nature of the instructions, the biocognitive strategies will vary, and therefore so will the peripheral response patterns.

This issue is of more than just academic importance. For example, in certain cases of hypertension the goal may be to lower peripheral resistance in the absence of heart rate changes, whereas for the treatment of angina pectoris the goal may be to lower the pattern of blood pressure and heart rate since the product of these two functions leads to reduced work of the heart and consequently reduced pain [30]. At the present time, however, we can only speculate as to what kinds of biofeedback procedures and instructions are best combined to produce these two different cardiovascular results, for there are as yet no controlled clinical studies on this issue.

CLINICAL APPLICATIONS OF BIOFEEDBACK: A CRITICAL OVERVIEW

At the present time there are over 100 published papers on clinical applications of biofeedback techniques. Many of these papers are based on collections of case studies, and it is difficult to interpret them. Several critical reviews have been written which cover a wide variety of clinical applications [e.g., 5,12,16,31,32], including tension headache, asthma, bruxism, muscular rehabilitation, epilepsy, hypertension, cardiac arrhythmias, Raynaud's disease, migraine, sexual responses, pain, and anxiety. Many of these reports represent only pilot studies and, while suggestive, all require carefully controlled clinical trials to evaluate them.

The clearest evidence for the efficacy of biofeedback therapy grows out of research on the regulation of skeletal muscle activity. This should not be surprising, since of all the bodily systems the skeletal muscles are under the most voluntary control, and feedback of their activity (both external and internal) are most extensive and available to the conscious brain. A clinical example is tension headaches, where the major symptom, pain, is often due to excessive and prolonged tension of the muscles in the forehead and neck. Stoyva and Budzynski have demonstrated that biofeedback for changes in frontalis muscle activity can enhance a patient's ability to voluntarily decrease forehead tension, which, in turn, leads to reduced pain. In one experiment,
they found that clinical improvement was significantly greater in the frontalis biofeedback treatment group compared to two control groups, one given false biofeedback, the other given no treatment at all [33].

There is little question that biofeedback can enhance the self-regulation of muscle activity. In fact, it has been demonstrated that subjects can gain control of individual motor units within a single muscle when provided with the appropriate biofeedback, even though these changes are well below the level of normal awareness [34]. However, Stoyva and Budzynski are careful to point out that gaining control over frontalis tension with biofeedback in the laboratory is but a prerequisite for clinical improvement. Patients must also practice self-regulation in real life situations outside the laboratory in order for the biofeedback training to have any long-term clinical value. This observation is understandable within the disregulation model, since there is no reason to expect that enhancing self-regulation via the addition of external feedback will in and of itself compensate for headache disregulation, especially if the etiology and maintenance of the disorder involves excessive environmental stresses (Stage 1) or maladaptive lifestyles (Stage 2). Stoyva and Budzynski are careful to tell their patients that they should use the enhanced awareness of muscle tension in their daily life as a signal for them to change their environment and/or their lifestyle (including coping style) in order to maintain low tension levels. If they do not, disregulation will continue and their headaches will likely return.

There are numerous other applications of muscle tension biofeedback under investigation, including applications to various neuromuscular disorders such as hemiplegia due to stroke, reversible physiological blocks due to edema, and Bell's palsy [see 32]. The extent of muscle retraining depends in large measure on the precise nature of the etiology, including the extent of central (Stage 2) and peripheral (Stages 3 and 4) damage. It is likely that such work will continue to progress, and that feedback techniques may develop into a standard adjunctive treatment in physical rehabilitation.

There are other more general muscle biofeedback applications of relevance to psychosomatic medicine and psychiatry. Whatmore and Kohli [6] claim that the training of whole body muscle relaxation can be used as a treatment for such skeletal, autonomic, and affective disorders as functional backache and neck pain, hyperventilation syndrome, hypertension, ulcers, anxiety, and depression. Like Jacobson [35] before them, they argue that chronic muscle tension in various parts of the body plays an important role in the development and maintenance of disregulation disorders, and through muscle biofeedback these functional disorders can be eliminated. Their neurophysiological model of "dysponesis," including case studies involving prolonged muscle retraining collected over a 20-year period, is described in The Physiopathology and Treatment of Functional Disorders [6]. While their approach is promising, particularly in their consideration of possible neurophysiological mechanisms and their emphasis on multi-process treatment programs, it must be recognized that their conclusions are based entirely on uncontrolled case reports. Carefully designed outcome studies have yet to be carried out demonstrating that the use of biofeedback training in the regulation of muscle tension has a central role in the treatment of these disorders.

A second major area of biofeedback therapy involves feedback for electroencephalographic (EEG) activity of the brain. The most well-documented studies are those by Sterman and colleagues [36] in which biofeedback training for EEG activity recorded from the scalp over the sensory/motor cortex is used to reduce specific epileptic seizures. Sterman claims that one particular sensory motor rhythm (SMR) between
12 and 14 hz must be regulated by the patient in order for reduction of seizures to occur. However, this conclusion may be premature, since other rhythms in this same region such as sensory/motor alpha (8–13 hz) may reflect similar brain processes. In any event, Sterman claims that when selected patients learn to inhibit sensory motor processes, reductions in seizures can occur. What is not known is whether training in general muscle relaxation (which by definition involves regulation of the sensory motor cortex) is sufficient for obtaining clinical improvement.

Like biofeedback for peripheral skeletal motor responses, it should not be surprising to learn that biofeedback for various EEG changes results in rapid self-control. This is because surface EEG typically reflects complex neural processes underlying normal voluntary control by the brain of its sensory, attentional, cognitive, and skeletal processes [2]. However, the claim that training for EEG alpha (without regard for cerebral localization) will lead to general relaxation and altered states of consciousness [37] is now recognized as being too simplistic [3,14]. Furthermore, altered states of awareness can so readily be achieved through simple cognitive, attentional, and somatic exercises already under a person’s voluntary control [e.g., 38,39] that biofeedback for EEG may be irrelevant to this goal.

Stoyva and Budzynski [40] point out, however, that for certain patients (e.g., those with insomnia) a multi-stage training procedure may be needed for inducing low arousal, drowsiness, and sleep: (1) training in forearm muscle relaxation (which is quite easy), followed by (2) training in frontalis muscle relaxation (which is more difficult), followed by (3) training in EEG theta (4–7 hz) activity (which is quite difficult). What becomes clear is that blanket statements for or against the use of biofeedback techniques are premature and likely incorrect.

The last class of biofeedback applications involves feedback for visceral and glandular responses regulated by the autonomic nervous system. One major area of application under investigation involves the treatment of migraine headache. In an uncontrolled clinical trial, Sargent and colleagues [41] have claimed that training migraine patients simultaneously to increase warmth in the fingers and decrease warmth in the forehead region using pattern temperature biofeedback leads to the reduction of migraine headaches. They combined biofeedback with instructions to imagine that one’s hands were heavy and warm, based on a cognitive self-regulation therapy called autogenic training [42]. The rationale for using “autogenic-feedback” training was suggested to them by the experience of a research subject who, during the spontaneous recovery from a migraine attack, demonstrated considerable flushing in her hands with an accompanying 10°F rise in two minutes. In subsequent work with 19 patients with migraine headache, Sargent et al. reported improvement in 63 percent.

Despite these encouraging findings, it is not known whether these same results could have been obtained with autogenic phrases alone, or if comparable results might have been observed through spontaneous remission and/or a “placebo” effect. Again, the issue is not simply whether biofeedback can be used to regulate temperature. As recently reviewed by Taub [43], highly localized control of skin temperature can be trained with temperature biofeedback. What is not clear is whether temperature biofeedback training is necessary and/or sufficient for the treatment of migraine. Nor is it known whether biofeedback for other parameters such as blood flow in the inflicted area will be more beneficial. In this regard, biofeedback for temperature and blood flow are currently considered as a potential adjunctive treatment for Raynaud’s disease. Successful cases have been described [43–45], but the interpretation of these cases is unclear.
Biofeedback for disorders of cardiac rhythms such as tachycardias and ventricular contractions (PVCs) has been investigated by Engel and colleagues [46]. There is little question that certain patients can reduce the frequency of PVCs by regulating heart rate. Interestingly, for some patients this is accomplished by decreasing sympathetic tone; in other cases it is achieved by decreasing parasympathetic tone. It appears that, depending upon the specific etiology of the arrhythmia, different components of the neural innervation must be self-regulated to achieve clinical improvement.

A major application of autonomic biofeedback involves feedback for blood pressure in the regulation of essential hypertension. Based on our blood pressure findings obtained in normotensive subjects [24–27], we studied seven patients with essential hypertension [47]. After between 5 and 16 control sessions, patients were given daily biofeedback sessions for lowering systolic pressure. Large decreases in pressure were obtained in five of the patients, ranging from 16 to 34 mmHg after 12 to 34 training sessions. Using a more sophisticated subject design where patients were taught to both decrease and increase pressure with systolic blood pressure biofeedback, Kristt and Engel [48] have replicated and extended these findings. In their study, daily blood pressure readings were obtained outside of the laboratory with a three-month follow up. These data suggest that blood pressure biofeedback can be used to help hypertensive patients regulate their pressure. However, it is not known whether blood pressure biofeedback is either necessary or sufficient for achieving clinical improvement. For example, Jacobson [35] reported that large blood pressure decreases could be obtained through general muscle relaxation, and Whatmore and Kohli [6] have extended this observation using biofeedback for muscle tension.

The utility of biofeedback in visceral self-regulation appears to be especially well documented in the training of rectosphincteric responses for the treatment of fecal incontinence. Engel and colleagues [49] used pattern biofeedback for training external sphincter contraction in synchrony with internal sphincter relaxation in six patients with severe fecal incontinence. During follow-up periods ranging from 6 months to 5 years, four of the patients remained completely continent and the other two were definitely improved. The technique was simple to apply and learning occurred within four sessions or less. Engel and colleagues emphasize that not only can sphincter activity be brought under voluntary control (a phenomenon long recognized) but that this control can be reintroduced in patients with chronic fecal incontinence, even when the incontinence is secondary to organic lesions. Clearly, the capacity for neural control must have been present in these patients for the biofeedback to have been effective.

A final example concerns the possible use of intestinal biofeedback in the treatment of functional diarrhea. Furman [50] reports that subjects can rapidly learn to reduce stomach and colon activity when given auditory biofeedback using a simple, electronic stethoscope. Furman applied this procedure to five patients with functional disorders of the lower gastrointestinal tract who manifested no organic findings. Response to treatment was uniformly positive. Furman claims that even patients who had experienced a lifetime of functional diarrhea and who had been virtually toilet bound are now enjoying normal bowel function. Although controlled studies have yet to be carried out using this technique, Furman's study illustrates how simple modes of feedback may be utilized by the patient and therapist as a team to aid in regaining control over a functional disorder.
THE PLACE OF BIOFEEDBACK IN THE TREATMENT OF DISREGULATION DISORDERS

It is clear that there are many potential applications of biofeedback in the treatment of physiological disorders. It is also clear that the exacting work of conducting controlled clinical studies to determine the validity and limitations of biofeedback for specific disorders with particular patients is just beginning. It will be years before definite conclusions can be drawn. Issues of expectancy, placebo responses, spontaneous remission, and others, must be considered [2,16,31] since they apply to any behavioral or biological treatment in psychiatry and medicine.

However, biofeedback research is providing more than just a potential clinical technique. It is providing a new research tool for understanding functional disorders, and, as I have illustrated, it is stimulating new neurophysiological analyses of normal and abnormal physiological self-regulation [2,3]. These analyses, in turn, serve to illuminate both the potential and limitations of biofeedback as a self-regulation therapy. They emphasize how biofeedback must be viewed as only one component of multi-process approach to treatment if long-term clinical gains are to be obtained.

For example, one issue of historical relevance to the development of biofeedback therapy concerns the so-called direct versus indirect approach [45,51]. The simple, direct approach is to provide the patient with feedback for a specific symptom for the purpose of self-regulating the symptom. Once self-regulation is acquired, the hope is that the symptom will remain under control and disappear. The indirect approach is broader in scope; it argues that patients should learn to regulate as many as possible of the underlying components or mediating processes contributing to the disorder, including environmental and behavioral factors.

The indirect approach argues that biofeedback can be used to signal both the therapist and the patient that the patient is currently thinking, feeling, or doing specific things that are detrimental to his physical or emotional health. A well-known example of this approach is the use of feedback in the treatment of obesity. In the same way that a scale helps direct the therapist and his obese patient in learning how to reduce food consumption and/or to increase exercise in order to reduce weight (rather than the patient spending hours on the scale attempting to lower his weight by thought processes alone), biofeedback for physiological disorders can be similarly employed. By means of the immediate, augmented feedback (with its associated increased bodily awareness) the patient can learn new ways of coping cognitively and behaviorally with his environment (Stage 2 CNS information processing) and/or he can learn to alter his environment (Stage 1) in such a way as to keep his physiological processes (Stage 3) within safer limits. In this respect biofeedback is similar to current psychotherapies, for they all provide corrective feedback [45] in the cybernetic sense [1].

By recognizing that disregulation disorders can have multiple etiologies requiring a multi-process treatment program, it becomes possible to determine more precisely what combination of factors is contributing to the disorder in the individual patient, and what combination or pattern of treatment approaches should be used in each individual case [2,3]. For example, if it were found in a given hypertensive patient that the high pressure tended to occur in anger-arousing situations, the therapist could employ a variety of cognitive and behavioral approaches, including, for instance, role playing, as a means of teaching the person better ways of handling his aggression. Or, if the patient had difficulty relaxing in situations of moderate stress, the therapist could employ a variety of cognitive and behavior relaxation procedures,
including muscle relaxation and meditation procedures, as a means of teaching the
person better ways of reducing excessive tension. As part of the treatment, however,
both the therapist and patient would profit from intermittent biofeedback (aug-
mented Stage 4) of blood pressure to ensure that the treatment regime was effective.
This use of feedback is similar to what the physician normally does when he monitors
the patient's pressure as a means of titrating drug effects. The difference here,
however, is the emphasis on the patient via the negative feedback (Stage 4) taking a
more active role in monitoring his physiological processes (Stage 3) and in self-
regulating his behavior (Stage 2) and environment (Stage 1).

There are numerous issues that need to be resolved, not the least of which is
economy. Is biofeedback too expensive to be considered on a large-scale basis,
especially if non-electronic relaxation procedures in and of themselves prove suffi-
cient to produce clinically significant long-term changes [39]? It seems probable that
certain patients with certain disorders will not require augmented biomedical
instrumentation to achieve improvement, but at this point it is premature to conclude
(and unlikely to happen) that this will be the case for all patients. The disregulation
model helps us to appreciate the multiplicity of factors contributing to functional
disorders, and helps us place factors such as secondary gain and suggestion (Stage 1)
and peripheral organ pathology (Stage 3 and/or 4) in a total treatment approach [2].
To the extent that severe pathology reduces the brain's ability to regulate the diseased
organ via normal and humoral factors, the limitations of biofeedback and other
behavioral approaches can be estimated. Here timing of treatment may be very
important, for a disorder may have progressed beyond the stage of reversibility by
biofeedback. The themes of self-regulation (broadly defined) and biofeedback (in
particular) have provided one impetus for developing the field of "behavioral
medicine" [5]. It places more responsibility for both sickness and health in the hands
of the patient, and suggests new directions for preventive medicine by manipulating
Stages 1 and 2 before organic pathology in Stages 3 and 4 has a chance to develop.

However, when we view functional disorders in terms of four stages of disregula-
tion, and we recognize that a combination of stages can contribute to the final
disorder in the individual patient, it becomes clear why increasing external feedback
in and of itself may not be sufficient for long-term clinical gains, even with the use of
home trainers and ambulatory feedback devices. As mentioned earlier, the corrective
internal negative feedback loop (Stage 4) in normal homeostasis not only provides
information, but with few exceptions it also provides a strong incentive (i.e., pain),
for the brain (Stage 2) to regulate itself for the sake of the organ's health (Stage 3)
and, therefore, ultimately its own. For this reason, it is necessary for the therapist to
consider both the information value and incentive value of biofeedback in the total
treatment program. If the latter is lacking, the former will be short-lived.

In cases of extreme pain or embarrassment (such as in fecal incontinence), this
adaptive mechanism provides a strong incentive for the patient to seek treatment and
follow the regime. In these instances biofeedback may be particularly effective in
aiding the patient to gain self-control. Unfortunately, in other disorders, such as
essential hypertension, this adaptive mechanism is minimal or lacking. As a result,
not only does the patient lack the feedback that something is wrong, but when he
receives this feedback from his physician, he still lacks the built-in internal negative
feedback which would motivate him to recover.

A good illustration of this point comes from one of our hypertensive patients who,
during the feedback sessions, was successful in lowering his pressure [45]. Over the
five daily sessions of a typical week, he would lower his pressure by 20 mmHg and
thus earn a total of over $35.00 for participating in the research. However, we consistently noticed that after the weekend, he would enter the laboratory on Monday with elevated pressures again. In interviews with the patient, the problem became clear. After earning a sizeable amount of money, the patient would go to the race track on the weekend, gamble, and invariably lose. The likelihood of teaching this patient to “relax” while losing at the race track through simple laboratory blood pressure feedback would seem slim, indicating that there is a need to change other aspects of the patient’s total life style, including developing some enduring incentive system for sustaining his health.

The motivation issue helps clarify the distinction between learning a self-regulation skill versus using that skill for the continued maintenance of one’s health. The long-term effectiveness of biofeedback, or, for that matter, any behavioral or biological treatment program involving self-control (e.g., taking drugs), ultimately depends on the patient’s motivation and ability to continue using the self-regulation skill. This distinction is an important one, for it helps us recognize the difference between developing behavioral procedures for helping patients to help themselves, as opposed to developing educational and social programs for leading patients to make effective, long-term use of the new behavioral technology. This writer is of the strong opinion that we are closer to solving the former than the latter. The ultimate clinical value of biofeedback and other self-regulation procedures for the treatment of disregulation disorders will hinge on our success in solving both of them.

MEDICINE AND THE INADVERTENT PERPETUATION OF DISREGULATION

One novel, and somewhat disturbing implication of the disregulation model is that, due to incomplete diagnosis and treatment of disorders involving disregulation, the traditional biomedical model inadvertently leads to the enhancement of disregulation. This applies not only to bodily disease but to human behavior more broadly [2,3].

As described previously, disregulation can be initiated and perpetuated at four basic stages. Often, the disregulation is initiated by stimulus demands from the outside environment (Stage 1), coupled with the brain’s reaction to them (Stage 2). If the brain is exposed to (or exposes itself to) environmental conditions which ultimately cause an organ system (Stage 3) to break down and develop a functional disorder, the appropriate internal negative feedback loops can be activated (Stage 4). This information can serve a vital negative feedback function, since it can direct the brain (Stage 2) to take corrective action if the organ is to survive. Even if the brain is busy attending to other stimuli in the outside environment, and thus fails to recognize the breakdown of a given organ, at some point the organ (if its negative feedback loop is intact) will generate sufficient negative feedback to redirect the brain’s attention. Any person who has experienced a strong stomach ache caused by overeating, eating under the wrong circumstances, or eating the wrong food, knows the power that negative feedback can have in commanding our attention and our subsequent behavior.

What “should” the brain’s response be to this internal stimulation? From a negative feedback, cybernetic perspective, it becomes clear that the brain should either change the external environmental demands (Stage 1) or its behavior (Stage 2) to maintain the health of the organ (Stage 3). Consequently, the intrinsic pain of the disturbed stomach (Stage 4) can help to keep our behavior in check by forcing us to stop eating, or to stop running while we are eating, or to not eat the dangerous food
again. It is only in this context that the pain is allowed to act as a negative feedback stimulus.

However, for many sociological reasons, man is not content to follow his initial biological heritage. He either feels no longer competent to change his environment or behavior, or simply does not want to. However, due to his highly developed brain and the resulting development of culture, he is no longer constrained to deal with the negative feedback by responding to organ dysfunction in terms of the body's normal structure. Instead, the typical patient would rather change his body structure (Stages 3 or 4) than change his lifestyle (Stage 2) or his environment (Stage 1), the two factors which together augment or cause the bodily dysfunction in the first place. Simply stated, man may choose instead to modify Stage 3 and/or 4 by certain extrinsic biological interventions. As would be predicted from the disregulation model, by artificially removing the negative feedback mechanisms, the brain becomes freed to continue behaving in maladaptive ways that could ultimately be deleterious to its survival. Lacking the stabilizing impact of the negative feedback regulation, the brain (and therefore its expression as behavior) goes more and more out of control [2].

Consider the stomach ache once again. At no time in human history has human culture so reinforced the practice of taking drugs to eliminate stomach aches caused by the brain's disregulation. The antacid commercials of the 1970s exemplify this value system. One commercial showed an obese man stuffing himself with apple pies or spaghetti. When he got a functional stomach ache, the conclusion was not: "The stomach and the rest of the body were not meant to eat like that—your stomach ache represents the necessary biological feedback mechanism that will help keep you from further abusing your body." Instead, what we heard was "Eat, eat—and if you get a stomach ache, don't change your external environment or behavior—rather, eliminate the internal discomfort artificially by taking a pill instead." Or the commercial depicted a family shopping at Christmas time, surrounded by crowds, struggling to hold the packages, rushing from counter to counter, continually inhibiting aggression caused by being bumped or offended in other ways. And, in the process, one of the members of the family got a stomach ache. The conclusion to this scenario based on the disregulation model "The stomach and the rest of the body were not meant to live like that—your stomach ache represents the necessary biological feedback mechanism that will help you from further abusing your body" was not the message of the commercial. Rather, what we were told was "Shop, shop—and if you get a stomach ache, don't change your external environment or behavior—rather, eliminate the discomfort artificially by taking a pill instead."

Simple antacids are mild drugs, and do not always work. When this happens, medicine comes to the rescue with stronger medication to quell the pain. Then when the organ becomes sufficiently abused so that an ulcer develops and internal bleeding occurs, does the person now listen to his stomach and radically change his external environment and behavior? Often not; what he does instead is to go to his surgeon and have the stomach repaired. Medicine, by dint of its continued technological success and ingenuity, is developing new and finer means of bypassing these normal adaptive feedback mechanisms. Thus, in extreme cases a patient can have a vagotomy, thereby eliminating the brain's capability to regulate the stomach directly. And if the trend in modern medicine continues, man can look forward to the day when he can simply go to his local surgeon and be fitted with a new, artificial "super" stomach that will not only be stronger, but will produce no pain.

In this situation, we would have a brain that was no longer constrained by the needs of its natural stomach. According to the disregulation model, such a brain
would be freed to continue and even expand upon the inappropriate disregulation that was the initial cause of the problem (overeating, running around too much, and the like).

The stomach is only one organ, of course. However, modern medicine is pursuing the same strategy for many of the systems of the body. Modern culture is continually reinforcing the idea that if the brain and its body cannot cope with its external environment, then the body and brain will simply have to alter itself medically to adjust to the increasingly maladaptive demands of the environment. According to the disregulation model, this prospect, if carried to an extreme, could have serious consequences for the structure and survival of the human species.

One should not come to the erroneous conclusion that biomedical intervention is always disregulatory, and, therefore, always has negative side effects in terms of disrupting natural self-regulation. The disregulation model can help us determine under what specific conditions, for what disorders, it is appropriate, not only in the short run but more importantly in the long run, to use pharmacologic and/or surgical interventions. The disregulation model helps us explain why we should not come to the simplistic conclusion that the direct correction of Stages 3 and 4 of disregulation by medical means should be the sole approach to treatment. Clearly, the environment (Stage 1) and our behavior (Stage 2) must be regulated in order to prevent disease. Responsible health care providers know that treating symptoms rather than causes is, in the long run, not effective. In the context of the present paper, treating symptoms rather than causes is, in the long run, inherently disregulatory. The feedback (Stage 4) of illness should serve as a corrective “negative feedback” stimulus that leads us to make, whenever possible, needed changes in the environment and in our behavior. It may be necessary for health professionals, government officials, and the public alike to accept and respect in Cannon’s [15] term the wisdom (and limitations) of the body (Stages 3 and 4) as it was originally designed, even though this may require more active regulation of the environment (Stage 1) by the brain (Stage 2) to keep the health and behavior of the human species intact. Biofeedback (Stage 5) can play a role in helping us to reach this goal.

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