GOOD BREATHING, BAD BREATHING

Breathing is behavior, a unique behavior that regulates body chemistry, pH.

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Breathing is behavior, a behavior that regulates acid-base physiology. Acid-base physiology is about pH balance of body fluids, including blood and the fluids that surround tissue cells. The effects of deregulated pH (or chemistry) on health and performance can be dramatic and profound. The way you have learned to breathe may have a much greater impact on you, than you might have ever imagined!

Good breathing behavior means proper regulation of body chemistry (pH), a chemistry that ensures electrolyte balance and proper distribution of oxygen. Bad breathing behavior means deregulating body chemistry. Breathing, like any other behavior, is regulated in varying degrees by learning, and thus by motivation, emotion, cognition, perception, and memory. Bringing together these two simple facts, that (1) breathing is a behavior subject to the principles of learning, and that (2) breathing regulates body chemistry (pH), means bringing together the biological and behavioral sciences in profoundly practical ways relevant to the lives of millions.

Hypocapnia

Breathing behavior regulates pH through proper exhalation (ventilation) of carbon dioxide (CO_2). In fact, pH plays a major role in the distribution of oxygen itself. Proper exhalation of CO_2, at rest, is only about 12 to 15 percent of the total CO_2 arriving in the lungs. The remaining 85 to 88 percent of the CO_2 is retained in the blood, and is absolutely vital to pH regulation. Exhalation of more than this relatively small amount of CO_2, results in a CO_2 deficit in the blood and other body fluids, a deregulated respiratory chemistry known as **hypocapnia**. Traditional common sense has misguided us into believing that CO_2 is poisonous. This superstition needs to be replaced with the facts.

Hypocapnia is the result of **overbreathing behavior**, the mismatch of breathing rate and depth. Its consequence is an increased level of pH, or **respiratory alkalosis**, which may have profound immediate and long-term effects that trigger, exacerbate, and/or cause a wide variety of emotional, perceptual, cognitive, attention, behavioral, and physical deficits that may seriously impact health and performance. Although the fundamental importance of CO_2 in body chemistry regulation is common knowledge to any pulmonary or acid-base physiologist, it remains virtually unknown by most healthcare practitioners, health educators, breathing trainers, and laypeople.

Overbreathing behavior

Overbreathing can be bad breathing, and like any behavior, it can be learned. Its effects on body chemistry may mediate "unexplained symptoms," misunderstood performance deficits, and acute and chronic "effects of stress," all of which may be falsely attributed to other causes. Good breathing behavior, on the other hand, can improve health and enhance human performance, as well as mediate "unexplained positive outcomes," placebo effects. Educating people about breathing as learned behavior, personalizes these effects, the good ones, and the bad ones. In this context, the effects of breathing on health and performance become *behavioral consequences*, rather than unexplained *clinical symptoms* and deficits.

Overbreathing behavior is commonplace. Based on surveys regarding ambulance calls, 60 percent of the ambulance runs in the larger USA cities are a direct consequence of symptoms precipitated by overbreathing. But, for every person who shows up in emergency, how many more show up in physician's offices with unexplained symptoms? For every person who goes to see their physician, how many more simply go to work? And for everyone who reports a "medical symptom," how many more suffer with unreported performance deficits, not even identified as symptoms? Half of the patients visiting outpatient clinics of the UK National Healthcare Services (NHS), receive a diagnosis of "functional disorder," where no organic factor is identified. And, unfortunately, they go from practitioner to practitioner without resolution. Hypocapnia may play a significant role in many of these cases, where it may mediate homeostatic deregulation attributed to stress.

Breathing learning and training

Millions of people worldwide teach and practice breathing behavior. They all agree that good breathing is basic to healthy physiology and psychology. They all claim one kind of success or another. They all have theories about how, why, when, and where breathing is good or bad. Traditions, culture, personal experience, incomplete knowledge, convenient facts, testimonies, misinformation, misunderstandings, myths, and superstitions are stitched together into diverse "schools of thought," including theory and practice, usually identified with its "innovative" creator and a supporting philosophy. Unfortunately, however, their knowledge is almost invariably restricted to the mechanics of breathing, such as the relaxation benefits of slow and diaphragmatic breathing, and does not include the underlying physiology and chemistry that truly account for the most profound effects of learned breathing behavior.

Breathing evaluation and training should address breathing as a behavior. People breathe very differently as a function of what they are doing, thinking, and feeling. Good body chemistry is vital to health and performance, and must be regulated despite the breathing acrobatics of talking, emotional encounters, and professional challenges. It needs to be maintained regardless of whether or not you are relaxed or stressed, excited or bored, active or inactive, working or playing, focused or distracted. To insist on slow breathing and relaxation, for example, during these times is not only unrealistic, but may also be counterproductive. Failure to directly address breathing behavior as it pertains to body chemistry means leaving out the most fundamental, practical, and profound factors that account for (1) the far-reaching effects of bad breathing, as well as for (2) the surprising benefits of good breathing. *Good respiration requires neither relaxation nor a specific mechanical prescription, save one: the varied melodies of breathing mechanics must ultimately play the music of balanced chemistry.*

In this article, we will examine (1) the physiology of hypocapnia and its effects on health and performance, and (2) the behavioral origins, the sustaining variables, and the management of overbreathing behavior. Learning good breathing is about *personal experiential expertise*, rather than *prescriptive professional expertise*. It is about *inside-out* personal exploration and development, rather than *outside-in* professional diagnosis and treatment. It helps us set the stage for a new emerging consciousness about health and performance, and unlike both traditional and alternative healthcare, it emphasizes the psychology of physiology, the role of learning in your own biology. Breathing behavior is center-stage to moving us through this doorway. Let's see why.

External respiration

External respiration is about the mechanics of breathing, getting oxygen into the lungs and regulating it in a way that ensures its diffusion into the blood. It is also about ensuring proper diffusion of carbon dioxide from the blood into the lungs, and its subsequent excretion into the atmosphere. It includes breathing rate, breathing depth (volume of air in a single breath), breathing rhythmicity (holding, gasping, sighing), locus of breathing (chest and diaphragm), breathing resistance (nose and mouth), and accessory muscle activity (muscles other than the diaphragm).

The diaphragm is the primary inspiratory muscle. Inspiration, at rest, typically includes only the **diaphragm**, and the **external intercostal muscles**. As the diaphragm contracts, the viscera are moved aside, and the lungs are drawn downward into the abdominal cavity, creating the negative pressure necessary for inhalation. Expiration, at rest, is passive; no muscle contractions need be involved, only the relaxation of the diaphragm and the external intercostals.

Accessory breathing muscles, used to assist external breathing, include abdominal, chest, back, and neck muscles useful during exercise, talking, singing, coughing, and so on. "**Chest breathing**" has reference to the use of accessory muscles, and "**diaphragmatic breathing**" has reference to breathing dominated by the diaphragm and external intercostal muscles. Chest breathing, at rest, may mean (1) using accessory muscles when they are not required, (2) using accessory muscles to do the work of the diaphragm, and worst of all, (3) using accessory muscles at the expense the diaphragm, i.e., "reverse" breathing. This, as we will see, increases the likelihood of deregulated breathing chemistry, disturbed acid-base balance.

Ventilation and its measurement

Gases (air) are measured by virtue of the pressures that they exert. When gases are mixed they each contribute to a **total pressure**. Each gas contributes a **partial pressure**. Total atmospheric air pressure at sea level, at 15◦ C and zero humidity, is 760 mmHg (millimeters of mercury). At sea level **partial pressure oxygen**, written **PO_2** is 159 mmHg (20.93%), and **partial pressure carbon dioxide**, written **PCO_2**, is 0.3 mmHg (less than 0.04%).

The **alveolus** is the fundamental respiratory unit. There are about 300 million alveoli. The **alveoli** are surrounded by about 280 billion **pulmonary capillaries**. Most of the gas exchange, O_2 and CO_2, takes place in the **alveolar-capillary unit**. Normal inhalation, at sea level, increases **alveolar PO_2** (average PO_2 in the alveoli) to about 104 mmHg. Because the **venous blood** arriving in the pulmonary capillary network contains only about 40 mmHg PO_2, rapid **diffusion** from the alveoli takes place, resulting in an **arterial PO_2** (**PaO_2**) of about 100 mmHg, most of which (98.5%) is transported to the tissues by **hemoglobin** in the red blood cells. Without pure oxygen (where PO_2 = 760 mmHg) or hyperbaric chamber pressure (where PO2 = 600 mmHg), the O_2 dissolved in blood plasma by itself is not adequate to support life.

Carbon dioxide is transported to the lungs where it is **(1) excreted** into the alveoli of the lungs for discharge into the atmosphere, and **(2) reallocated** to the body for proper maintenance of acid-base physiology. ***Reallocation of CO_2*** means reflexive coordination of breathing depth and rate, where **arterial PCO_2** (**$PaCO_2$**), which under normal circumstances, is maintained at about 40 mmHg for normalizing blood plasma pH (about 7.4). PCO_2 in capillary venous blood, at rest, is about 46 to 48 mmHg, whereas inspired atmospheric air contains only about 0.3 mmHg PCO_2. Because pulmonary capillary PCO_2 equilibrates with **alveolar PCO_2** as a result of diffusion, alveolar PCO_2 levels must also be continuously maintained at about 40 mmHg. Thus, if alveolar PCO_2 increases, so too does arterial PCO_2, and if alveolar PCO_2 drops as a result of overbreathing, so too does arterial CO_2. *Bad breathing is when learned breathing behavior disturbs the proper regulation of CO_2 allocation.*

Overbreathing and hypocapnia is measured with a capnograph, an instrument used to measure average alveolar PCO_2. In a lung-healthy person the alveolar PCO_2 is equivalent to $PaCO_2$. These instruments are used worldwide in emergency medicine, in critical care, and during surgery for gas monitoring and regulation purposes; these are medical applications. This article is about the educational applications of capnometry instrumentation, where it is used for evaluating and managing overbreathing behavior, specifically the educational use of the **CapnoTrainer**.

Overbreathing reduces levels of alveolar PCO_2, resulting in **local hypocapnia**, i.e., reduced CO_2 levels in the lungs, which by itself may directly increase the likelihood of bronchial constriction and airway resistance, and reduce lung compliance. As a result, breathing may become more labored and contribute substantially, both physically and psychologically (e.g., fear of not getting your breath), to the likelihood of a breathing-struggle episode, even an asthma attack.

Acid-base balance, hydrogen ion concentration, and pH

Acid-base balance is about the regulation of **hydrogen ion concentration**, written $[H^+]$, in body fluids (50% of body weight). These fluids are both **intracellular** (fluids within cells, 32% body weight) and **extracellular** (fluids outside cells, 18% body weight). Extracellular fluids include **blood plasma**, **cerebrospinal fluid**, **lymph fluid**, and **interstitial fluid** (fluid immediately surrounding cells). Maintaining correct levels of $[H^+]$, also known as pH, is absolutely critical to healthy physiology, healthy psychology, and optimal performance. Because pH, mathematically speaking, is the negative logarithm of $[H^+]$, as pH rises $[H^+]$ decreases, and as pH drops $[H^+]$ increases.

The pH of water is 7.0, but it contains an equivalent concentration of hydroxyl ions $[OH^-]$ which offsets $[H^+]$, and is thus said to be "neutral" (buffered). Thus, solutions with a pH below 7.0, where $[H^+]$ is greater than $[OH^-]$, are **acidic**. And, solutions with pH levels above 7.0, where $[OH^-]$ is greater than $[H^+]$, are **alkaline**. The range of extracellular pH levels *is very restricted*. Blood plasma, for example, is a slightly alkaline aqueous (water) solution, with a normal pH range of 7.35 to 7.45. Plasma **acidemia** is a pH below 7.35 (although this is still alkaline), and plasma **alkalemia** is a pH above 7.45. Plasma pH levels below 6.9, and above 7.8, are fatal. Levels below 7.35 and above 7.45 can result in physical symptoms, psychological changes, and performance deficits.

Hydrogen ions are generated by the body as a result of metabolism. Most of these ions are "**utilized**," which means that once they are produced, they are "used up" in either the synthesis of other body substances, like glucose, or they are **oxidized**, converted into CO_2 and H_2O. Before hydrogen ions are utilized, or before they are excreted as in the case of protein metabolism, they are "**buffered**" (neutralized) by **bicarbonates** (**HCO_3^-**). Thus, pH level is maintained and **metabolic acidosis** (lower pH) is prevented. Examples of metabolic acids include **lactic acid**, generated in its largest quantities during anaerobic metabolism, and **ketoacids**, generated as a result of fat metabolism. The hydrogen ions of these acids are continuously utilized, and thus the bicarbonates used to buffer them, are also continuously restored.

The **Henderson-Hasselbach (H-H) equation**, known to virtually everyone who has studied basic physiology, tells us that pH in extracellular fluids is regulated by the relationship between the presence of **carbon dioxide, PCO_2**, regulated by breathing, and **bicarbonate concentration**, **$[HCO_3^-]$**, regulated by the kidneys: **$pH = [HCO_3^-] \div PCO_2$**. Changes in the numerator of the equation, bicarbonate levels, are generally slow (8 hours to 5 days), whereas changes in the denominator, carbon dioxide, are immediate. This places breathing center stage in moment-to-moment acid-base regulation. In the case of blood plasma, a $PaCO_2$ of about 40 mmHg results in a pH of about 7.4. Ventilating off too much CO_2 by breathing too deeply, or rapidly, or both, constitutes overbreathing behavior, which lowers PCO_2 below 40 and raises the pH above 7.4, making plasma (and other extracellular fluids) too alkaline.

Generally, $PaCO_2$ levels below 35 mmHg constitute hypocapnia: 30-35 mmHg is mild to moderate, 25-30 mmHg is serious, and 20-25 mmHg is severe hypocapnia. One of the direct consequences of CO_2 deficit is smooth muscle constriction, including, among others, muscles in: (1) the gut, leading to increased likelihood of spasm, pain, and nausea, (2) the lungs, leading to bronchial constriction, (3) the placenta, leading to reduced blood flow and reduced supply of nutrients to the fetus, and, (4) the vascular system, leading to cerebral artery constriction, coronary constriction, vascular resistance, vasospasm, and higher blood pressure. Constriction of smooth muscle as a result of hypocapnia, depending on the person, can result in symptoms of all kinds, including most of the symptoms identified with the "effects of stress."

Reflexive compensatory breathing

Fundamental breathing reflexes are regulated by spinal chord and brainstem mechanisms. These centers regulate breathing, from breath to breath, based on pH of the surrounding cerebrospinal and interstitial fluids, along with the PCO_2, but surprisingly not PO_2. In addition to receptor sites in the nervous system, however, there are also receptor sites in the **aorta** and the **carotid** arteries which are sensitive not only to arterial CO_2 and arterial pH, but also to arterial PO_2 (PaO_2).

When the numerator of the H-H equation, bicarbonate concentration, is disturbed by a metabolic condition, there is normally **reflexive breathing compensation**, where PCO_2, the denominator of the equation, rises or falls, balancing the ratio, and thus keeping the pH somewhere within its normal range, in the case of blood plasma, 7.35 to 7.45. For example, when bicarbonate concentration is reduced as a result of **ketoacidosis** (diabetes), overbreathing decreases arterial PCO_2 and restores extracellular pH toward normal. Overbreathing, in this case, despite its potential negative side effects, is an adaptive response to ketoacidosis.

Another important example of reflexive respiratory compensation is during severe physical exercise. During transition from aerobic to anaerobic exercise, abnormal amounts of lactic acid begin to be generated. Hydrogen ion production begins to “outstrip” its utilization, and there may no longer be an adequate bicarbonate reserve, resulting in **lactic acidosis**. Fortunately, lung capacity normally exceeds cardiovascular capacity, so that acidosis during strenuous exercise can be compensated for through overbreathing, $PaCO_2$ reduction. Observing PCO_2 levels during exercise, on a stationary bike or on a treadmill, gives sports and fitness enthusiasts a rough indication of their **anaerobic threshold**: when CO_2 level drops breathing compensation for lactic acidosis has begun.

The brainstem chemo-regulatory management of breathing relies principally on the diaphragm for its control. Thus, learned use of accessory muscles during times of stress and challenge, chest breathing, may lead to deregulation of the brainstem mechanisms, resulting in symptoms of hypocapnia, usually attributed to “stress” rather than to the *response to challenge*, in this case deregulated breathing behavior. Unfortunately, practitioners, who do not understand breathing from a behavioral perspective, neither evaluate the likely behavioral contributions to the deregulated denominator of the H-H equation nor educate their clients/patients about how to manage breathing behavior and its personal consequences.

Internal respiration

Internal respiration is about ensuring the transport of oxygen in the blood from the lungs to the cells, and the transport of metabolic carbon dioxide from the tissue cells into the blood and to the lungs.

Once CO_2 and H_2O enter the interstitial fluid (around the cells) as a consequence of cellular respiration, they diffuse into the plasma of the blood. About 90 percent of the CO_2 then diffuses into the red blood cell. The balance of about 10 percent remains dissolved in the plasma, the **dissolved PCO_2**. The presence of CO_2 in the red blood cell, as we will see, is crucial to oxygen distribution. Carbon dioxide is **hydrated** (combines with H_2O) to form **carbonic acid**: $CO_2 + H_2O \leftrightarrow H_2CO_3$. The carbonic acid **dissociates** (breaks down) into hydrogen and **bicarbonate ions**: $H_2CO_3 \leftrightarrow H^+ + HCO_3^-$. The increased presence of hydrogen ions, H^+, means that the red blood cells become less alkaline, i.e. the pH of the fluid (cytosol) in red blood cells drops. The bicarbonates, HCO_3^-, diffuse into the blood where they buffer acids, e.g. lactic acid.

The amount of CO_2 generated by tissues determines precisely how much carbonic acid is formed, and thus the pH of the red blood cell, as well as the amount of bicarbonate entering the plasma. The presence of CO_2 gas and the drop in pH within red blood cells, independently and together, alter the spatial constitution of the hemoglobin, which decreases its affinity for oxygen, i.e., it more readily gives up its oxygen and raises plasma PO_2 level; this change is known as the **Bohr Effect**. Thus, hemoglobin more readily distributes its O_2 to the tissues that need it, while simultaneously buffering the hydrogen ions to restore normal pH in red blood cells. Reduced pH and increased PCO_2 not only predisposes hemoglobin to release its oxygen, but also to release **nitric oxide** (a gas), a potent vasodilator. The result is increased blood volume and flow, which increases oxygen and glucose supply to cells that generate more CO_2, cells with elevated metabolism.

Increased PCO_2 levels lead to *increased* (1) supply of oxygen (more blood), (2) supply of glucose (more blood), (3) PO_2 (O_2/ml blood), and bicarbonates for buffering acids. Proper PCO_2 regulation means that red blood cell chemistry reflects surrounding tissue metabolism. Overbreathing reduces dissolved PCO_2, and thus decreases CO_2 and carbonic acid in red blood cells. This means reduced hydrogen ion concentration, increased pH in red blood cells. The effect on hemoglobin is twofold: (1) increased affinity for O_2 (Bohr Effect), reducing the likelihood of its release into the plasma, and (2) diminished release of nitric oxide, resulting in vasoconstriction. This translates into less oxygen (**local hypoxia**), less glucose (**local hypoglycemia**), and reduced buffering capacity for the tissues in need. Reduced nitric oxide also elevates plasma platelet level, their aggregation, and “adhering” propensity, thus elevating the likelihood of blood clotting.

Hypocapnia and electrolyte balance

Hypocapnia has a direct impact on the electrolyte balance of extracellular fluids. In the brain, for example, sodium ions in the interstitial fluid are exchanged for hydrogen ions in the neurons. Although this lowers the pH of the interstitial fluid toward normal, which is desirable, the excessive sodium ions increase neuronal excitability, contractility, and metabolism. Even more unfortunately, this increase in metabolism occurs when the neurons can least afford it, at a time of reduced blood flow and deficits of both oxygen and glucose. This reduces the threshold for anaerobic glycolysis, increasing the likelihood of lactic acidosis in neurons, which may contribute to yet further physical and psychological symptoms and deficits. It also may lead to **excitotoxin** production and **antioxidant** depletion.

Hypocapnia alters the balance of calcium and magnesium in muscles, which increases the likelihood of tetany, spasm, weakness, and fatigue. This includes skeletal muscles with serious implications for athletes and fitness enthusiasts. And, it includes smooth muscles, where imbalance may exacerbate or trigger migraine, angina, and electrocardiogram abnormalities. The transport of sodium and potassium ions into cells at large, in exchange for hydrogen ions, may also lead to symptoms and deficits associated with sodium and potassium deficiencies.

Respiration and kidney physiology

The **nephron**, the kidney's basic structural and functional unit, is responsible for the purification and filtration of the blood. During filtration, bicarbonates leave the blood and become part of nephron **filtrate**, including water, electrolytes, glucose, amino acids, vitamins, small proteins, creatinine, and urea. As these substances pass through the nephron, many of them are selectively **reabsorbed** and returned to the blood, including sodium and bicarbonate ions. Other substances are **secreted** into the filtrate from the surrounding cells and capillaries, such as hydrogen and ammonium ions. Carbon dioxide plays the key role both in the return of bicarbonates from the filtrate back into the blood, and the synthesis of new bicarbonates lost through the buffering of unutilized hydrogen ions, generated during protein metabolism.

Carbon dioxide and H_2O, in the filtrate, diffuse into the **tubular cells** that surround the filtrate, to form carbonic acid: $CO_2 + H_2O \leftrightarrow H_2CO_3$. Just as in the case of red blood cells, carbonic acid dissociates into hydrogen and bicarbonate ions: $H_2CO_3 \leftrightarrow H^+ + HCO_3^-$. *The bicarbonates in tubular cells are transported into the surrounding capillaries*, and are thus fully reclaimed for general circulation. *The hydrogen ions in these cells are transported into the filtrate in exchange for sodium ions*. Sodium ions in the tubular cells, together with the bicarbonate ions, are **co-transported** to the capillaries, and thus returned to general circulation. And, the hydrogen ions, now in the filtrate, combine with more bicarbonate ions in the filtrate to form carbonic acid: $H^+ + HCO_3^- \leftrightarrow H_2CO_3$. The carbonic acid in the filtrate dehydrates into CO_2 and H_2O, which then diffuse into the same tubular cells, where once again they form carbonic acid in the tubular cells, and the cycle begins anew. A nearly identical process, also requiring CO_2, provides for the synthesis of new bicarbonates that replace the ones lost in the buffering of acids generated during protein metabolism. In this case, however, H^+ in the filtrate is combined with sodium phosphate and excreted, rather than being utilized in the formation of H_2O reabsorbed by tubular cells.

Overbreathing results in CO_2 deficit in the kidneys, which means that less bicarbonate is recovered from the filtrate, and new bicarbonate is no longer formed. This may mean that bicarbonate ions, crucial to the buffering of metabolic acids, such as lactic acid produced during exercise, are depleted. The consequences may include (1) compromised physical endurance in sports and fitness enthusiasts, and (2) the appearance of fatigue symptoms associated with chronic stress, where adequate buffering of even small amounts of lactic acid is compromised. The exchange of hydrogen ions for sodium ions is also reduced, and may contribute to development of sodium deficiency and its associated symptoms.

Syndromes, symptoms, and deficits triggered, exacerbated, or caused by overbreathing

Together, the effects of all of the above considerations can be profound and dramatic, effects well recognized in clinical physiology. It has been standard procedure, for example, for many years, even now, in emergency medicine, to induce hypocapnia for reducing bleeding and swelling in the brain. Although potentially lifesaving in cases of head trauma, it is now recommended against because of the potentially dangerous side effects that may outweigh its benefits. Unfortunately, many of us engage this same "emergency procedure," without realizing it, when we go to work, face challenges, and communicate with others. Hypocapnia can result in serious changes in brain chemistry, leading to profound physical and psychological changes. Here are some of its effects:

NEUROLOGICAL SYNDROMES: epilepsy, ADD, ADHD
COGNITIVE DEFICITS: attention, learning, thinking, problem solving, memory
PSYCHOMOTOR DISTURBANCES: coordination, reaction time, integration
EMOTIONAL REACTIVITY: anger, anxiety, low mood, frustration tolerance
PERFORMANCE ANXIETY: public speaking, test taking, music recitals

PSYCHIATRIC SYNDROMES: phobias, panic attack, anxiety syndromes, depression
PERSONALITY CHANGES: self-esteem, confidence, cognitive style, emotional posture
PSYCHOLOGICAL DEFENSIVENESS: denial, self-talk, dissociation, disconnectedness
STRESS SYMPTOMS: fatigue, generalized anxiety, burnout, and physical symptoms
CARDIOVASCULAR: angina, heart attack, arrhythmias, irregular heart beat, nonspecific pain, ECG abnormalities
VASCULAR SYNDROMES: hypertension, migraine phenomena, digital artery spasm
BREATHING DISORDERS: bronchial constriction and spasm, asthma symptoms and attack
GASTRIC SYNDROMES: irritable bowel syndrome (IBS), nausea, cramping, bloatedness, non ulcer dyspepsia
BIRTH COMPLICATIONS: fetal health and premature birth
MUSCLE COMPROMISE: spasm, hyperreflexia, pain, tetany, weakness, fatigue, and stiffness
NEUROMUSCULAR DYSFUNCTIONS: repetitive strain injury (RSI), pain, injury, fibromyalgia
BLOOD: red blood cell rigidity (effects of calcium), thrombosis (blood clotting)
PHYSICAL ENDURANCE: altitude sickness, acute fatigue, chronic fatigue, effort syndrome
SLEEP: apnea and other disturbances

Here are some of the acute (immediate) symptoms triggered by overbreathing:

BREATHING: shortness of breath, breathlessness, feelings of suffocation
CHEST: chest tightness, pressure, and pain
SKIN: sweaty, cold, tingling, and numbness
HEART: palpitations, irregularities, rate
EMOTION: anxiety, apprehension, worry, emotional outburst, crying
STRESS: tenseness, fatigue, weakness, headache, hypertension
HEAD: dizziness, lightheadedness, fainting, black-out, confusion, disorientation
SENSES: blurred vision, dry mouth, sound seems distant, reduced pain threshold
PSYCHOLOGICAL SHIFTS: memory discharge, hallucinations, self-esteem
COGNITION: attention deficit, loss of focus, inability to think
CONSCIOUSNESS: feelings of "other worldliness," sense of disconnectedness
PERIPHERAL CHANGES: trembling, twitching, and shivering
MUSCLES: tetany, spasm, weakness, fatigue, and pain
ABDOMEN: nausea, cramping, and bloatedness.

The Henderson-Hasselbach equation rewritten

Medical practitioners are interested in the organic factors that disturb the numerator of the H-H equation, the bicarbonate concentration. Breathing, the denominator, is considered to be a reflexive chemo-physiological compensatory mechanism that contributes to the restoration of acid-base balance. Integrating behavioral science with the H-H equation, however, means examining behavioral and psychological variables that disturb the denominator of the equation. Thus, the equation might be rewritten as follows: acid-base regulation (pH) = physiology ÷ breathing behavior, or even physiology ÷ psychology, where psychology makes its entry through its effects breathing behavior. The implications are impressive.

In revisiting this equation, it is important to take note that pH not only has a profound effect on behavior, but that behavior has an immense effect on pH. Why isn't this common knowledge? Why is the content of this article new to most readers? Why aren't practitioners everywhere implementing this knowledge? The answers are really very simple: (1) Medical practitioners practice what they've learned, and provide the services for which they are licensed. They are generally not behavioral scientists, psychologists, counselors, therapists, teachers, consultants, or breathing coaches. Even if they had the skills, and the time, the healthcare delivery system does not provide well, either philosophically or financially, for patient education services. (2) Behavioral practitioners have never heard of the H-H equation. Many of them are "afraid of" physiology, and consider anything that references physiology as being beyond the scope of their practice and license. Thus, the otherwise obvious applications, become hidden and remote, lost in the divisions of cultural thinking.

Behavioral origins of overbreathing behavior

Why do we learn deregulated breathing behavior? The answers to this question are no more a mystery than the same questions about any other behavior, adaptive or maladaptive; the same behavioral principles apply. And, like other behaviors, overbreathing can be quickly and easily learned, and unfortunately, like so many habits, can be challenging to disengage, manage, modify, or eliminate. Most learning is unconscious. Very little of it is intentional or conscious. Deregulating breathing may be learned based on some of the following behavioral principles:

Instrumental (operant) conditioning, or learning based on **reinforcement**, is an underlying biological learning principle for the acquisition of many behaviors. Access to emotions, such as anger, may serve as a defensive reinforcement. "Reaching for air" may be reinforcing, offering resolution to the "survival" metaphor for "drowning." A sense of "control" may be achieved, through intentional regulation, external manipulation. Intentional use of accessory muscles (falsely) resolves a sense of distrust of the body. "More air" introduces a (false) sense of security.

Secondary gain, resulting from unexplained symptoms and deficits, may lead to learning the role of "victim." The breathing-induced symptoms and deficits become the basis for visiting healthcare practitioners, as well as sympathy, support, and attention from family and friends.

Classical (Pavlovian) conditioning, also an underlying biological learning principle, may lead to the development of phobias about "getting your breath," which may develop at an early age, or at any time, as a result of conditions such as asthma. The experience of the physical sensations of breathing itself may, through classical conditioning, trigger emotional responses. And, overbreathing itself may become a classically conditioned response to specific emotional, social, physical, and even professional experiences.

Stimulus generalization, basic to biological learning, means that although overbreathing may be learned under one set of circumstances it may "generalize" to similar but different sets of circumstances. This may be true not only perceptually but also metaphorically, where it may become embedded in seemingly unrelated comprehensive patterns of coping behavior.

Vicious circle behavior may develop, where the solution to a problem, becomes the problem. Depleting buffers through chronic overbreathing, in predisposed individuals, may mean that even during aerobic activities there are not adequate buffer reserves to manage lactic acidosis. Thus, even minimal effort, such a walking through a supermarket, may result in lactic acidosis. The resulting unbalanced H-H equation, where the numerator has now decreased, requires compensatory reduction of PCO_2 (the denominator) through overbreathing, a solution to what is also a contributing cause.

Cognitive learning can play a major role in the development of overbreathing. Misconceptions, misinformation, personal beliefs about biological self, experiential unfamiliarity with breathing, misinterpretation of physical sensations, distrust of the body, defensive thinking, self-talk, and intentional breath manipulation all contribute to setting the stage for learning deregulated breathing behavior.

State dependent learning may be the consequence of overbreathing, where radical shifts in brain chemistry and associated states of consciousness may provide the context for learning new behaviors, as in the case of drug dependence. Alternative cognitive styles, emotional postures, and senses of self may then become dependent upon the state changes brought about by breathing behavior. The consequence may be ***chronic overbreathing behavior***, especially in cases of emotional trauma, where state change may set the stage for learning an alternative personality, one based on defensiveness and safety.

Fight-flight reflexes may provide the context for learning to overbreathe. Overbreathing may be learned as a defensive response to specific challenges e.g., performing before an audience, or confronting a distressed partner. It may mediate shifts in consciousness, through its immediate and direct effects on brain chemistry, that provide for **dissociation**, a gateway for disconnecting from emotional vulnerability and traumatic memory. Even as a compensatory reflex for acidosis as a result of disease, toxicity, and organ failure, overbreathing may be reconfigured through learning and experience, as are other basic reflexes. Adverse physical conditions, e.g., injury, in fact, can set the ideal stage for learning to overbreathe.

Breathing is a unique behavior. It points to the in inseparability of physiology and behavior, where breathing plays a key role both in homeostasis from a biological perspective and in self-regulation from a behavioral perspective. Breathing behavior plays both obvious and subtle roles in the regulation of health and performance. The following considerations attest to its special place in mediating "unexplained symptoms," placebo effects, and the "effects of stress:"

●Breathing is a "perpetual" behavior. It emerges at all times in all places.
●Breathing is necessarily woven into virtually every behavioral topography.
●Breathing is a trigger for emotions, memories, thoughts, physical symptoms, senses of self, and personality.
●Breathing is a gateway that sets stages, creates backdrops of meaning, establishes contexts, and changes states.
●Breathing is controlled centrally from diverse neurophysiological sites, as well as locally by cells and tissues.
●Breathing is voluntary and involuntary, conscious and unconscious.
●Breathing is critical to homeostasis: acid-base balance, electrolyte balance, and delivery of oxygen and glucose.
●Breathing is vital to social behaviors such as verbal communication.
●Breathing is reflexive in nature, although complex in its relationship with the environment and other behaviors.

CapnoBreath Training

"Capno" means carbon dioxide. **CapnoBreath Training** is about learning and teaching "capno regulation," adaptive respiratory chemistry, within a wide range of breathing mechanics. It means precision coordinating of breathing rate and depth through reflex control of the diaphragm, restoring control to the brainstem mechanisms that regulate breathing based on pH, PCO_2, and O_2. This reflex mechanism can be easily deregulated, consciously or unconsciously as a consequence of learning. CapnoBreath training is about setting the stage for reinstating this reflex mechanism.

CapnoBreath learning requires integrating knowledge of internal breathing with external breathing, chemistry with mechanics. Emphasis is on *the relationship dynamics* of breathing mechanics for achieving good chemistry, rather than on specific "mechanics" prescriptions. There is no inherently correct breathing rate, no correct depth, and no correct rhythm. Different breathing patterns, such as during the breathing acrobatics of talking or singing, serve different objectives. *The varied melodies of breathing mechanics must ultimately play the music of balanced chemistry.*

CapnoBreath Training requires the use of a **CapnoTrainer**, a computer-operated capnograph designed for educational rather than medical applications, which provides real-time PCO_2 feedback for observing, evaluating, teaching, and learning breathing behavior. The practical guidelines of doing CapnoBreath coaching can be organized into seven categories, all of which include evaluation, education, and training. Some steps are accomplished in parallel, some sequentially, and depending on training objectives, some not at all. CapnoBreath Training includes the following:

(1) Exploration: originating and sustaining factors and circumstances;
(2) Identification: dysfunctional breathing patterns, when and where;
(3) Phenomenology: the experience of breathing and its effects;
(4) Knowledge-learning: understanding basic breathing concepts;
(5) Mechanics-learning: play dynamics for awareness of breathing as behavior;
(6) Somatic-learning: play dynamics for awareness of the effects of breathing; and
(7) State-learning: breathing through consciousness.

(1) Exploration: originating and sustaining factors and circumstances

Learning about breathing is not simply making a measurement. It is about a partnership exploration, client and trainer. Remembering that breathing is behavior, is vital to a productive exploration. Breathing changes immediately and significantly as a result of thoughts, feelings, people, physical experience, sense of self, and specific life circumstances, e.g., public speaking, or communicating with an upset person. A client may breathe well in front of you, but deregulate immediately in front of her/his spouse, supervisor, or teacher.

During an initial evaluation session, the breathing coach conducts a **breathing interview** for purposes of identifying deregulated breathing patterns, symptoms and deficits associated with breathing habits, and the possible origins of overbreathing. During the interview PCO_2 is continuously monitored for observation of changes in chemistry and associated changes in breathing mechanics. Observations are noted by the breathing coach on a checklist, and a self-evaluation checklist is completed by the client, as a part of breathing interview. The following kinds of considerations are explored, discussed, and evaluated:

- What are the specific breathing complaints?
- When did the complaints first appear?
- What are the associated symptoms and deficits?
- What emotions and thoughts accompany the symptoms?
- What kind of self-talk about breathing is there?
- How does the breathing behavior interfere with performance?
- What are the specific triggers, including when, where, and with whom?
- Is there fear associated with breathing? How so?
- Is breathing a "struggle?" How so?
- Is the deregulation specific or pervasive?
- Are there "unexplained" symptoms that tie together with the breathing?
- How does your client cope with the breathing challenges? What does s(he) do?
- What are his/her opinions about why s(he) breathes the way s(he) does?

Learned overbreathing behavior may be triggered by any of the following:

- task challenges, e.g., cars, planes, equipment operation
- social situations, e.g., meeting people, authority figures, public speaking

● emotional circumstances, e.g., relationship issues, anger problems
● physical limitations, e.g., pain, injury, discomfort
● learning environments, e.g., testing, school, skill acquisition, computers
● past trauma, e.g., accidents, emotional abuse
● disease, e.g., asthma

Reviewing the physiological breathing record in the context of behavioral observations, client comments, and information gathered during the breathing interview, provides for development of testing strategies for experiential exploration of breathing and its effects.

(2) Identification: dysfunctional breathing patterns, when and where

Breathing mechanics are invariably involved in deregulated chemistry, and are a very important part of the evaluation. Significant deregulated mechanics include:

●failure to breathe diaphragmatically
●failure to exhale completely
●failure to allow transition time between breaths
●reaching for air through deep breathing
●intentional manipulation of breathing
●mouth breathing
●using accessory muscles, when not required

These breathing mechanics are significantly *correlated with* overbreathing, however they may not necessarily be the *cause of* overbreathing. Mouth breathing and overbreathing, for example, although correlated with one another may both be caused by worrying about breathing. It is important to understand that correcting any one of these mechanics may increase the likelihood of regulated breathing, *but may not significantly address the fundamental causes of overbreathing*, e.g., dissociating from traumatic memory.

Dysfunctional breathing patterns can be identified by monitoring breathing physiology with a CapnoTrainer. When clients see their breathing on a computer screen, the information convincingly speaks for itself. It allows clients to see for themselves how they are breathing, how mechanics interact with chemistry (PCO_2), and the effects that may be triggered. Identifying faulty breathing patterns, however, is only the beginning of a very personal exploratory process: the factors that originate and sustain these patterns must be addressed. There are many ways to explore these factors with your client. Testing for these factors can be accomplished in a variety of ways, by monitoring breathing behavior during: guided recollection of previous experiences, public sharing of previous experiences, story telling, physical challenges, thought-challenges, emotional challenges, psychodrama, breathing mechanics challenges, en vivo testing, and intentional overbreathing. Testing constitutes evaluation, education, and training.

Breathing behavior, like other behaviors, is tied to specific contexts, states, and stimuli. Measurement during actual circumstances, en vivo testing, is undoubtedly the best of all worlds. Examples include monitoring breathing during: relationship challenges, making an oral presentation, recital performances (playing the piano for an audience), piloting in a flight simulator, before performing a sport (getting ready to swing a golf club), reading a paragraph and being tested on it, composing a paragraph on the computer, and taking a competency test. The impact of overbreathing on these activities can be devastating: emotional outburst, anxiety, anger, attention deficit, loss of focus, poor memory, inability to think clearly, perceptual-motor deficit, and feelings of low self-confidence. CapnoTrainers can be used by trainees in the field through Internet coaching, where the practitioner can observe live physiology through "remote assistance."

(3) Phenomenology: the experience of breathing and its effects

Absolutely crucial to successful CapnoBreath training is exploring the phenomenology of breathing, the personal consciousness associated with breathing as an experience. This consciousness is about emotions, thoughts, sense of self, and relationship to people and environment. Changing breathing changes consciousness. The *"psychology of breathing"* includes (a) how you respond to the experience of breathing behavior, (b) how breathing behavior affects you, and (c) how you respond to the effects of breathing.

(a) Misinterpreting the meaning of physical changes associated with breathing can increase the likelihood of overbreathing. Fast breathing, for example, is easily misinterpreted, consciously or not. Fast breathing is not overbreathing. It is not inherently good or bad by itself; it depends. It may, however, lead to overbreathing because of its psychology:

● It can make it “seem like” you are having difficulty getting air.
● It can make breathing seem urgent, which may introduce worry and anxiety.
● It can lead you into chest and mouth breathing, which make fast breathing easier.
● It can make you feel like “something must be wrong, I’m breathing too fast.”
● It can lead you to conclusions like, “I’m anxious, I can’t relax, I’m overwhelmed.”

What does your client say about her/his breathing? Self-talk sets the stage for overbreathing by creating a sense of urgency. Examples of negative self-talk are: “I can’t get my breath.” “There’s not enough air in here.” “I won’t be able to breathe, if…….” “I’m going to have an ‘attack’ if I don’t get my breath.” “Oh, Oh, I’m not breathing enough, I’m holding by breath.” “Breathing is such a struggle, I feel exhausted.” Learning constructive self-talk is essential to learning good breathing: “I don’t have to “get” my breath. It will come.” Learning to trust the respiratory system by getting to know it is fundamental to learning good breathing; this is discussed in the next section.

(b) Learning about how breathing affects you means changing your breathing and observing the outcomes. **Intentional overbreathing** is an important discovery and training tool for people who already overbreathe. By taking proper precautions, neither the breathing coach nor the trainee, need be afraid of intentional overbreathing. After all, overbreathing is the problem, and as a behavior, it must be addressed. In fact, fear of overbreathing and its effects may be contribute to the problem. ***Warning:*** Do not introduce intentional overbreathing to clients with medical conditions, without first checking with the client’s physician.

Learning what hypocapnia “feels like” is a very important part of evaluation and training. During intentional overbreathing, look for triggered symptoms, memories, and shifts in consciousness. Does changing PCO_2 level remind your client of earlier times, places, or people? Intentional overbreathing will often trigger experiences very similar to ones previously experienced in real life circumstances. This kind of experience during an exploratory and/or training session often has a profound impact on clients, and becomes enormously instructive as to how deregulated breathing can mediate previously unexplained or misunderstood physical symptoms and performance deficits.

The rate of recovery from hypocapnia is a very important indicator of deregulation. Frequently people who have serious overbreathing problems become prisoner to the effects of overbreathing, where the effects themselves, e.g., breathlessness, motivate them to breathe deeper and faster, thus worsening the effects. The cause of the problem unknowingly becomes the (self-defeating) solution to the problem. In real life, clients may begin overbreathing only to find themselves trapped in vicious circle overbreathing behavior for hours at a time. And, like any other behavior, it may not change until there is a contextual shift, e.g., leaving the scene.

(c) Learned responses to the effects of hypocapnia vary considerably and depend upon biological individual differences and previous learning histories. Some people have anxiety reactions when they begin to feel disconnected from their environment, others feel safe and relieved, while others yet feeling nothing significant. The setting in which the effects are experienced also plays an important role in determining one’s response to them, again based on learning history.

In people who are chronic overbreathers, restoring normal levels of PCO_2 may result in a sense of vulnerability, anxiety, and unhappy memories. They quickly retreat into overbreathing, despite its associated adverse side effects. Learning good breathing in this case is not only threatening, but if learned is very unlikely to be generalized into life at large. The solution in this case is psychotherapy, where breathing becomes a gateway for titrating personal dynamics.

(4) Knowledge-learning: understanding basic breathing concepts

It is important to know the underlying physiology that accounts for the positive outcomes of breathing training, to make the implicit explicit, wherein relevant mechanisms are addressed directly, rather than incidentally. Making the implicit explicit for trainees provides for direct focus on the variables that count, the ones that provide for the efficacy. This approach points the way to far greater efficacy of breathing training, not to mention its credibility. Faulty assumptions and understandings about the physiology of breathing are implicit in training practices everywhere, which unfortunately, in many cases, may actually lead to counterproductive practice:

(a) Clients are often told that breath holding means underbreathing, when in fact, it may constitute a brainstem reflex for restoring PCO_2 levels, a compensatory response to overbreathing. “Remember to breathe” is often a recommended antidote to stress, when if fact it is usually overbreathing that leads to the observed symptoms of homeostatic deregulation. Underbreathing behavior, contrary to popular opinion, is rare in healthy people. An important exception is **hyperinflation**, where people take a deep breath, immediately abort the exhale, reach for another breath, and trap themselves in the **anatomical dead space** of the upper airways, where diffusion of O_2 and CO_2 is minimal.

(b) Deep diaphragmatic breathing is often counterproductive practice, a practice that may create a problem, rather than offer a solution. Diaphragmatic breathing is vital to success, but deep breathing, under most circumstances, leads promptly to hypocapnia and its unfortunate effects, e.g., anxiety. Good respiration should not be held hostage to relaxation.

An interesting example is the work of a psychologist in Europe, who gave her corporate clients relaxation training homework exercises, which included diaphragmatic practice. Not infrequently they would report their displeasure in doing the exercises, which she had interpreted as "Type A" discomfort with inner experience. Upon working with a CapnoTrainer, however, she discovered to her surprise, that many of her clients had been practicing overbreathing! Their discomfort, and sometimes, outright refusal to do the assigned homework, was precipitated by the effects of hypocapnia.

(c) Slow breathing is often labeled as "good" and rapid breathing as "bad." There is nothing special about the physiology of slower breathing, but rather it is the psychology of slower breathing that is special. It sets the stage for improving breathing chemistry. It encourages diaphragmatic breathing, allows for complete exhalation, teaches patience between breaths, and reduces the urgency for getting another breath. It statistically favors learning adaptive breathing behaviors, but does not by itself necessarily constitute better physiology.

(5) Mechanics-learning: play dynamics for awareness of breathing as behavior

Developing familiarity and a sense of comfort with, and confidence and trust in, breathing mechanics, is essential to learning good breathing. This means *playing with breathing mechanics* for learning how they relate to good and bad respiratory chemistry. Breathing mechanics are typically acrobatic during life's daily challenges, which often include continuous and unabated conversation, laced with emotion, thoughts, and attitudes. While talking breathing may be jerky or even, aborted or extended, fast or slow, oral or nasal…..utterly dysrhythmic, but nevertheless, these mechanics must be subordinated to brainstem reflex mechanisms, that coordinate rate and depth for healthy chemoregulation. Mechanics play typically includes (a) diaphragmatic and chest breathing, (b) exhalation and inhalation, and (c) breathing rate and depth.

(a) Diaphragmatic breathing is essential to maintaining healthy body chemistry: chemoregulation is achieved primarily through diaphragmatic control. Adaptive diaphragmatic breathing is effortless, efficient, quiet, slow, and gentle, but not deep. Diaphragmatic breathing simply happens, and it does so in accordance with brainstem chemoregulation mechanisms. It usually doesn't need your help.

Chest breathing, the use of accessory muscles when they are not required, is "controlled breathing." It often triggers muscle posturing, even in muscles entirely unrelated to breathing, which can result in tension and pain, even headache. It is inefficient, labor intensive, and can make breathing seem difficult, even exhausting. It usually requires faster breathing, which may introduce a sense of urgency and anxiety about breathing. It makes completion of exhale difficult, which can trigger breathlessness, chest tightness, and worry about getting the next breath. It may create a sense of feeling confined, restricted, and trapped, setting the stage for feeling defensive and insecure. Chest breathing makes breathing intentional, and "requires" that you "take" a breath! Intentional breathing, conscious or unconscious, interferes with diaphragmatic control. It brings a sense of struggle to breathing, a behavior that should otherwise seem automatic, effortless, and easy. Chest breathing is a quick way to deregulate chemistry.

Learning good diaphragmatic breathing also means knowing how "not to breathe." Practicing both the desired diaphragmatic mechanics and the undesirable chest breathing mechanics uses the principle of **negative practice**. If you can breathe either way by choice, and are aware of their defining sensations and consequences, you are more likely to regulate even in the most challenging of circumstances.

(b) Exhalation and diaphragmatic breathing, acting in concert with one another, are mechanical keys to ensuring proper chemoregulation. Not allowing for relaxed and passive exhalation translates into:

- fear of not getting enough air;
- worry that the next breath may not come in time;
- being in a hurry to take your next breath;
- distrust of the body, so that breaths must be intentionally "taken;"
- restricted range of inhalation, giving a sense of limitation that is real and scary;
- making it impossible to take a deep breath;
- requiring you to compensate with faster breathing; and
- sensitizing you to breath transition, where waiting for a breath becomes intolerable.

Exhaling is passive, and is about letting go, "allowing." It does not require muscles. It means "letting" the air out by relaxing the diaphragm. The exhale should not be forced, not "pushed out." Forcing the air out, may motivate you to "take" a deep breath. Forcing air out, translates into using accessory muscles, which may then lead to overbreathing. Learning to be comfortable with transition time **desensitizes** you to the waiting period. *Convert patience to meditation*.

Inhaling is active. Nevertheless, it too should be "allowed." The brainstem reflex mechanisms ordinarily do not need your assistance. Being in a hurry usually means "taking" breaths, intentional breathing, and is likely to lead to overbreathing. Mechanics play allows for learning how the brainstem reflex engages your inhale, how is happens on its own accord. See how small the breath can be, and still be comfortable.

(c) Learning about the relationship between breathing depth and rate is fundamental to CapnoBreath training, and requires PCO_2 feedback monitoring. Maintaining good chemistry while breathing more rapidly means that depth must be adjusted accordingly. Learning to maintain PCO_2 levels within the healthy window, 35 to 45 mmHg, during fast and slow breathing develops a sense of how chemoregulation takes place. It provides the basis for reinstatement of brainstem reflexes.

(6) Somatic-learning: play dynamics for awareness of the effects of breathing

Fundamental to behavioral management of hypocapnia is learning the somatic (physical) subtleties of PCO_2 changes. The experiential effects of hypocapnia vary greatly from person to person. Learning to physically identify the effects of hypocapnia, as in the case of breathing mechanics, is achieved through *chemistry play*. What does it physically feel like to breathe at 35 mmHg vs. 30 mmHg, or 25 vs. 30 mmHg? Trainees learn by monitoring PCO_2 levels and changing them intentionally, moving down to one level and back to the previous level. If someone can overbreathe down to 30 mmHg on purpose, and then know how to get back to 35 mmHg, an awareness of the differences begin to emerge. Ultimately, the result is awareness of even small changes in chemistry along with the mechanical shifts required for restoring good chemistry. Train first with PCO_2 feedback. Then train without it.

How does playing with PCO_2 feedback specifically affect the individual? Are there noticeable changes is muscle tension: in the jaws, around the eyes, below the ears, around the vocal chords, across the forehead, and in the upper back, shoulders, chest, and abdomen? Is there spasm or tetany? Is skin temperature changing: in the fingers, hands, feet, face, or ears? Does the person cold, or hot? Is there numbness, tingling, light-headedness, feeling of being off-balance, blurred vision, dry mouth, stiffness, or forehead pressure? Is there ringing in your ears? Do sounds seem closer or more distant? Does the person feel nausea, pain, or cardiac changes (e.g., a racing heart)?

Basic principles of breathing mechanics for raising PCO_2 levels include coaching clients to use the diaphragm, to breathe more slowly, to allow the exhale, to be present for the transition, to allow the inhale to come on its own, and to observe how little air is actually required for achieving maximum comfort. During this time ask your client what s(he) feels, physically and emotionally. Are physical sensations changing, disappearing, or emerging? Are emotions engaging or disengaging?

(7) State-learning: breathing through consciousness

State-learning is about teaching and learning to breathe through consciousness. It is about internalizing chemoregulatory control. It is about embedding a sense of breathing chemistry within consciousness as a whole, where it can orchestrate good breathing during times of rest and relaxation, while facing difficult tasks and relationship challenges, and during times of gymnastic breathing while communicating or exercising. It means embedding awareness of good and bad chemistry in the multiple contexts of consciousness.

Good breathing is regulated based on how YOU feel on the inside, rather than what IT looks like from the outside. It is not bound to specifically arranged circumstances outside of ourselves, such as music, a pleasant environment, relaxation techniques, or prophylactic breathing prescriptions, e.g., six breaths per minute. These are only half way measures, measures that may be useful in assisting learning while transitioning from bad breathing to good breathing. Successful transition from awareness *of the outside* to awareness *from the inside*, involves learning how breathing alters consciousness. This consciousness is about arousal, attention, presence, emotions, thoughts, sense of self, and relationship to people and environment. Healthy breathing is about learning to breathe inside-out, intuitively, rather than outside-in, prescriptively.

Good breathing is ultimately about "embracing" instead of "bracing." It is about engaging life challenges, rather than "defending from" them. Embracing means "being present," connecting, and learning, where defending (or bracing) means armoring, isolating, and disconnecting. Breathing reveals the psychological nature of physiology, the "meaning" contained within physiology. Traditional focus on health and life style emphasizes the meaning of fight-flight physiology and its management, including the role of prescriptive breathing for relaxation. The focus of CapnoBreath Training is on embracement physiology, where breathing behavior serves as a dynamic center of balance within the diversity of states of consciousness. *This means understanding breathing as behavior rather than simply as manipulated physiology*:

(a) State-learning involves exploring the effects of self talk, imagination, and thought on breathing, and how they determine your experience of breathing and can assist you in changing your breathing behavior. Clients learn to align their breathing behavior with their internal dialogue, body-mind with self.

(b) State-learning involves weaving good breathing into the fabric of emotion and motivation, and discovering first hand how breathing can trigger, exacerbate, redirect, diminish, eliminate, or change excitement, passion, humor, anxiety, tension, disorientation, arousal, aggression, frustration, depression, euphoria, relief, and safety. Clients learn to come into these feeling states with good chemistry through being present, embracement.

(c) State-learning involves folding good breathing into performing tasks, mentally rehearsing actions, active listening, focusing, resting, communicating, socializing, fitness training, learning new information, thinking, and remembering. Clients learn to engage these activities through the consciousness of good breathing chemistry.

(d) State-learning involves changing breathing chemistry and observing its effects on sense of self, including self-esteem, defendedness, self-confidence, social competence, and alternate personality styles. Clients learn to bring good chemistry into challenging states of self through recognizing signs of deregulated breathing. Breathing becomes a navigational guide to preventing and/or reversing dissociative state changes, by reconnecting to their bodies and becoming available to themselves and others. Breathing is now experienced as shifts in consciousness. Clients breathe with their whole bodies rather just with their lungs.

Successful training

Experiential familiarity with the chemical and mechanical dimensions of breathing, means embedding the experience of breathing in personal consciousness. It means increased presence and availability to people and circumstances, improved attention to learning and connecting, and healthy emotional and intuitive self-regulation. In summary, achieving successful changes in breathing behavior involve learning to:

● maintain good chemistry across a wide spectrum of breathing mechanics;
● reinstate chemo-reflex control of diaphragmatic breathing;
● distinguish between defensive and embracing physiologies;
● be present for feelings, intuitions, and images arising from physiology;
● recognize what "respiration feels like," rather than what "it looks like;"
● experience the whole body "breathing," not just the lungs;
● breathe "inside-out" intuitively, rather than "outside-in" prescriptively;
● think and talk differently about your breathing (stop negative self-talk);
● recognize personal signs of deregulated breathing;
● trust your own breathing through mechanics awareness training;
● breathe diaphragmatically, slowly, quietly and gently, but NOT deeply.
● allow the exhale, and avoid "doing the exhale;"
● allow the inhale to arrive, and avoid "taking" the breath;
● desensitize to transition time between breaths (reducing fear and anxiety);
● breathe through your nose (teaches confidence and patience);
● stop worry about underbreathing, which takes care of itself;
● think about experiences that engage positive feelings; and
● breathe from your consciousness.

Short-term solutions for acute hypocapnia

Many people, as a result of overbreathing, become trapped in vicious circle breathing behavior (see case #1 below). They misinterpret their symptoms as meaning that getting enough air is difficult and that it requires a struggle, e.g., breathlessness, chest tightness, and dizziness. The misconceived solution, of course, is faster and/or deeper breathing, which worsens the symptoms and verifies suspicions and prejudices about their physical competence. A self-fulfilling prophecy is the consequence. This kind of deregulated pattern may result in episodic crises. What are some short term interventions that your clients can utilize for crisis management? Here are some recommendations:

●Exhale completely, but not forcibly.
●Extend the transition times from exhale to inhale.
●Breathe with your diaphragm, if possible.
●Breathe slowly, but NOT deeply.
●Breathe through your nose.
●Breathe gently and quietly.
●Stop negative thoughts about your breathing.
●Think about people, circumstances, and events that engender positive feelings.
●Use earplugs, and listen to your breathing. Make it absolutely as quiet as possible.
●Walk hard, or do other exercise, to create additional amounts of CO_2.

Do the above with a paper bag, if desired. Breathe into a medium sized paper bag for 5 to 10 minutes, or until you feel comfortable. This procedure will restore CO_2 levels little by little. Breathe into the bag as quietly as possible. We suggest that you carry ear plugs and a paper bag with you at all times, should you have a need for crisis management.

Here is a partial listing of some of the factors that may trigger or prevent overbreathing behavior.

TRIGGERING FACTORS	PREVENTION FACTORS
Worry about breathing	Breathing self-confidence, trust
Using accessory muscles (chest)	Diaphragmatic breathing
Intentional breathing	Allowing breathing to happen
Deep breathing	Quiet effortless breathing
Rapid breathing	Slow quiet breathing
Failure to exhale completely	Allowing for exhale & its transition
Negative self-talk & thought about breathing	Self-affirmations about breathing
Misinformation about breathing	Education about the facts
Emotional responses to hypocapnia symptoms	Desensitization, counterconditioning
Mouth breathing	Nasal breathing
Discomfort with breathing sensations	Experiential exploration
Anxiety between breaths	Relaxation and imagery
Breath holding	Breath consciousness
Fight-flight challenges	Breathing inside-out
Dissociative thinking	Embracing instead of defending

Case study #1: unable to go to work

A physiotherapist, previously an Olympic athlete (running) was frequently unable to go to work. On certain mornings, upon not being able "get her breath," for reasons unidentified, she would call in "sick," and struggle the rest of the day with breathing. At the end of each day she did fitness workouts, which restored her sense of well being. Based on her own interpretation of the symptoms, she was certain that she was underbreathing, and somehow unable to get ample air. She had struggled with this condition for several years.

We tested her PCO_2 levels with the CapnoTrainer at rest, and challenged her with tasks and emotions, and could find nothing, no overbreathing, although based on our breathing interview, we were convinced that there was a problem. We then coached her into intentional overbreathing by increasing breathing volume, and within not more than a minute, we had recreated her struggle. She immediately claimed that "this is what happens to me, and now I won't be able to get out of it, for the rest of the day!" With the CapnoTrainer, however, she could see for herself: she was overbreathing, not underbreathing. She had confused symptoms of overbreathing with underbreathing.

We immediately showed her an easy way out. Our coaching emphasized use of the diaphragm, passive and relaxed exhale (no use of muscles), allowing for transition between breathes, quiet and small breaths (and still be comfortable), and thoughts about happy events. Within three or four minutes her PCO_2 levels normalized and she felt relaxed and relieved. We re-educated her about the physiology of breathing, taught her some simple prophylactic techniques for emergency application, and gave her homework for learning good breathing chemistry. She learned that her workouts, in fact, had set the stage for (1) disruption of vicious circle overbreathing behavior, and (2) reinstatement of adaptive breathing behavior.

Case study #2: exercise

A competitive athlete, also a physiotherapist, became fearful of doing exercise because it triggered unwanted emotions. She had discontinued her workouts altogether for the previous six months, and had gained 10 kilos. She was even afraid to hike with friends. It is significant to note that breathing training was an inherent part of her work as a physiotherapist, although in her own case, she had no idea as to the role of breathing behavior in her symptoms.

We tested her for PCO_2 levels on an exercise bike with the CapnoTrainer. Upon doing any significant degree of exercise, her PCO_2 levels plummeted to 20-25 mmHg (serious hypocapnia), and her unwanted emotions were immediately triggered. Practicing the restoration of normal PCO_2 levels with the CapnoTrainer during exercise eliminated the emotional episodes. She was able to return to doing physical exercise without further incident.

Case study #3: emotional outburst at work

An elementary school teacher experienced emotional episodes in the middle of class for reasons unknown. She cried for no apparent reason. And, she felt trapped by her breath. The problem was serious; it interfered with her doing her job.

We tested her for overbreathing with the CapnoTrainer at rest, and while challenged with tasks and imagination. We found no overbreathing. Upon doing an overbreathing induction, when at about 28 mmHg PCO_2, she burst into tears. Coaching as previously described, led to immediate cessation of the emotional outburst. In this case we recommended consultation with a mental health counselor or psychologist. Clearly a referral was in order; breathing wasn't her only problem.

Case study #4: safety in overbreathing

A middle-aged realtor had been diagnosed with emphysema. After having spoken with her doctor, she was convinced that because of her condition, she couldn't get enough air.

We examined her PCO_2 level with the CapnoTrainer and found it to be less than 25 mmHg. Although, CO_2 retention in some patients with lung disease may account for low PCO_2 levels observed with a capnometer, this was not true in her case. Upon elevating the PCO_2 levels through coaching, she felt her face and hands warm, as a result of vasodilation, but as she came into normal range she reported feeling vulnerable, emotional, and with memories that she did not like.

In this example, the patient was suffering with chronic hypocapnia, a place of disconnection where she was able to dissociate by changing her state of consciousness, leading her to a place of safety, protected from her sense of vulnerability. In fact, overbreathing behavior is almost invariably present, in cases of emotional abuse and posttraumatic stress syndrome. Breathing behavior in these cases becomes a way of exploring feelings and memories during psychotherapy.

Case study #5: overbreathing while at rest

A successful businessman, with a reportedly happy family life and lots of friends, found himself frequently in the emergency room of the nearest hospital with unexplained symptoms. The last incident was on British Airways on his way to London. His struggle with breath nearly required landing the flight at the nearest airport, before starting over the Atlantic Ocean. Upon arriving in London, he ended up in emergency, again with no explanation for his symptoms. His next trip to London was coming in less than a week. He was now in our office looking for a quick solution.

We performed a standardized PCO_2 assessment with the CapnoTrainer, and found that during challenges there was no overbreathing, but that during rest or idle periods he went immediately into moderate overbreathing, about 30 mmHg. We then recreated his last experience on British Airways through an imagination induction: we retold his own story about boarding the aircraft, step by step. His PCO_2 level plummeted to 18 mmHg within about four minutes! This extreme hypocapnia precipitated all of the symptoms and deficits that typically brought him into emergency.

We had a short time before his flight. Thus, we taught him only some short-term prophylactic ways of preventing overbreathing, so that he could make his trip to London. We saw him again, by coincidence, about six months later. He was eager to tell us about he had never again had an attack, and that all was now well under control.

Case study #6: overbreathing for pain relief

A computer consultant with hypocapnia and had been referred to us by a chiropractor, who also owned a CapnoTrainer. The chiropractor was stumped and wanted our assistance. The client suffered an automobile accident and then spinal surgery that had gone bad.

The CapnoTrainer revealed that he indeed was overbreathing and suffering with chronic hypocapnia. Upon restoring normal PCO_2 levels through PCO_2 feedback and coaching, he began to feel tingling in his lower leg and neck, followed by pain in his upper back. Upon his return to overbreathing the tingling and pain ceased. There was no medical evidence in his record that suggested that his overbreathing might be compensation for a metabolic disturbance.

The client rented a CapnoTrainer for home use. Upon doing his afternoon workout on an exercise bike, he noticed that his PCO2 levels had normalized, but that there had been *no signs* of tingling or pain. Subsequently, he learned that his strenuous exercise had masked the tingling and pain experience, and that if he had simply tolerated the experience while not exercising, the symptoms would have abated within a few minutes. He had unconsciously learned pain management through overbreathing. He successfully retrained himself over a period of two months with the CapnoTrainer. Overbreathing and hypocapnia are no longer a problem.

Case study #7: yoga

A mental health counselor sat down for a demonstration during a workshop. He told us that he had hypertension, and suffered with a diastolic pressure that hadn't been less than 95 mmHg in many years. We monitored his breathing with the CapnoTrainer and took his blood pressure. His breathing rate was 32 breaths/minute, his PCO_2 was 25 mmHg, and his diastolic blood pressure 96 mmHg. When we informed him that he was "hyperventilating," he was resistant. He told us about his expertise on the subject of breathing and how he had been training clients for many years. He also told us about his ten years of yoga practice and that he knew the principles of good breathing. We then reminded him that despite his expertise, he was still overbreathing.

We asked him to do his yoga. After about ten minutes his breathing rate was six breaths/minute, his PCO_2 was normal, and his diastolic blood pressure was 74 mmHg! When we revealed the blood pressure reading he was in a state of disbelief. He had taken his blood pressure almost every day for many years, and had never seen a reading below 95. We asked him whether or not he had ever taken his blood pressure *while doing his yoga*. The answer was, "no." Blood pressure went down while restoring good breathing chemistry during meditation, but thereafter immediately increased upon resuming overbreathing, the only time during which he had recorded his own blood pressure.

Case study #8: chemical sensitivities

A psychologist reported that she suffered with a chemical sensitivity that led within minutes to a loss of consciousness (syncope), a problem that she had suffered with, episodically, for more than 30 years. No one could adequately explain to her the triggers that may have mediated her symptoms, including her hypoglycemic swings and radical drops in blood pressure. The possibility of loss of consciousness was dangerous, requiring her to take special precautions, such as having to be accompanied by others during local outings as well as during extended travel. The consequences were debilitating and expensive.

A breathing interview, along with education based on use of the CapnoTrainer**,** revealed that her detection of chemicals "set the stage" for the triggering of overbreathing behavior. The resulting hypocapnia may have lowered the threshold for the consequences of her blood sugar and blood pressure changes, one of which was fainting. Many of her "chemical sensitivity" symptoms, including the fainting, may have been falsely attributed to the chemicals rather than to the effects mediated by her breathing behavior. Although some of the symptoms were, of course, indeed a result of the chemicals, the clinicians looking after her, NOT recognizing the role of learned breathing behavior, attributed ALL of the symptoms to the "chemical" sensitivity and/or other physiological conditions. Attributing symptoms only to known organic variables without regard to learning principles that underlie physiological homeostasis, is common place in healthcare; in physiotherapy, for example, therapists usually attribute symptoms and deficits only to the injuries being treated, and do not consider the effects of meditating behaviors such as breathing.

Breathing, in the presence of chemicals, was not the only behavior that changed. Self-talk, imagination, emotions, attitude, and self-perception changed within seconds, all of which together constituted a unique configuration of learned behaviors, a personalized "syndrome," triggered by her detection of chemicals (and other circumstances). This configuration established a psychological context, including a "sense of self," which may have set the stage for learning vicious circle overbreathing, where specific self-talk, for example, may have served to confirm her suspicions about not being able to "get enough air," while simultaneously providing the basis for some the symptoms attributed to her sensitivities, e.g., breathlessness, dizziness, and other effects of oxygen and glucose deficit in the brain.

Like most all behavior, she unconsciously learned overbreathing somewhere previously in her life. Subsequent interviews helped her discover one of the possible origins of this learned behavior, a circumstance that she vividly recalled during pregnancy when, because of the position of the child, the pressure on her diaphragm resulted in a struggle with "getting enough air." Her conscious struggle with air during pregnancy may have "metaphorically" generalized to other challenging circumstances. By systematically exploring changes in her PCO_2 levels with the CapnoTrainer, in combination with mechanics awareness training, she learned good breathing, breathing that transcended external circumstances and permitted reinstatement of the brain-stem chemo-regulation breathing reflex. She no longer faints in the presence of chemicals.

Breathing coaching with a CapnoTrainer

Breathing coaching is about education, not about diagnosis and treatment. Professionals of all kinds can learn to be breathing coaches, including healthcare practitioners, mental health practitioners, human service professionals, corporate consultants, and educators. In fact, most anyone can get involved. We all breathe. It is always important, however, to keep your eyes open. A referral may be in the making. Breathlessness, for example, is not just a sign of overbreathing, but may be a sign of cardiovascular compromise that requires immediate medical attention. Partnership with other professionals is always the wisest approach to helping people to learn new breathing behaviors.

Educational applications of capnography are wide ranging: athletic/fitness training, alternative healthcare, cardiovascular rehabilitation (e.g., hypertension), chiropractic and osteopathic practice, corporate coaching/training (anger and stress management), learning disabilities (e.g., attention deficit), marriage and family counseling (e.g., couples counseling), mental health counseling, nursing (pregnancy and child birth), occupational therapy, patient education (e.g., epilepsy), performance training (music recitals, public speaking, flight training), physical/rehabilitation therapy (e.g., pain management), psychology and psychiatry (e.g., anxiety disorders), speech therapy, respiratory therapy (e.g., asthma management), and social work.

The Japanese "word" for "breath" perhaps best describes good breathing. The word is a picture of "self" and "heart." It expresses the essence of my message about breathing and the psychology of physiology. The consciousness of the union of self and heart is embracement. And, good breathing is vital to the integrated consciousness of self and heart.

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