

# Exercise Endocrinology Principles and Catecholamines

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## Abstract

The sympathoadrenal system is essential for the liberation of fuel, delivery of nutrients, and suppression of various mechanisms which counter such actions. Studies point to an incredibly potent lipolytic response to catecholamines as well, both directly and indirectly. The processes by which NE and E liberate fatty acids from adipose tissue will be analyzed. More importantly, implications of how the endocrine system affects pre-, mid-, and post-exercise nutrition will be introduced. Ultimately, fuel utilization in the midst of physical exertion, and anabolism following, are regulated by complex ligand-receptor complexes. Moreover, these can be optimized by various training and diet protocols. Further subjects discussed include: a historical look at the post-workout meal, catecholamine's affect on endogenous insulin secretion, implications of lipid insoluble and soluble hormones, alpha and beta receptors, and a host of other factors vital to the inducement of an anabolic environment.

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The importance of nutrition following training-induced homeostatic disruption can be traced to our most ancient of writings. Esau, the first born of Isaac, in what is estimated to be 1800 B.C. appears to have had incredible genetics. His training sessions, however, were not found in the gym, but rather in the field as he hunted the most ferocious of beasts. So vital was the post-workout meal to the father of the Edomites that he sold his birthright to his brother Jacob for it!

And Jacob sod pottage: and Esau came from the field, and he was faint: And Esau said to Jacob, Feed me, I pray thee, with that same red pottage; for I am faint: therefore was his name called Edom. And Jacob said, Sell me this day thy birthright. And Esau said, Behold, I am at the point to die: and what profit shall this birthright do to me? And Jacob said, Swear to me this day; and he sware unto him: and he sold his birthright unto Jacob. Then Jacob gave Esau bread and pottage of lentiles; and he did eat and drink, and rose up, and went his way: thus Esau despised his birthright. Genesis 25:19-34

A further illustration of ancient nutritional practices can be found over 3000 years ago. It was at this time that one of Israel's greatest warriors, the mighty Jonathan, son of Saul, after battling Israel's most fierce enemies and defeating what appeared to be unbeatable odds, "put forth the end of the rod that was in his hand, and dipped it in an honeycomb, and put his hand to his mouth; and his eyes were enlightened." Today, our most brilliant scientists are confirming the amazing recuperative powers that this rapidly absorbed substrate would incur.

It is astonishing to note that, until today, such a protocol has not been matched (though even now, after thousands of years of advancement, some still hold to the unscientific, wholly unsupported practice of consuming fructose, fat, and fiber upon cessation of training).

But what of pre-workout historical nutrition? The variety of diets has ranged from the extreme to the sensible. On the former end, ancient Romans and Grecians would eat the heart of a lion to obtain its courage, while on the latter it is said that Charmis of Sparta would consume figs before a training bout. It appears that even as late as the 1936 Olympic Games that many of the worlds top nutritionists had not nailed home the most accurate of methods for pre-workout prep. In one German publication, Schenk describes the athletic diet for those competing in Berlin:

"The Olympic athletes competing at Berlin frequently focused upon meat, the athletes regularly dined on two steaks per meal, sometimes poultry, and averaged nearly half a kilogram of meat daily, **pre-event meals regularly consisted of one to three steaks and eggs, supplemented with meat juice extract.**"

Historically, I believe men such as Galen (born AD 129, , Pergamum, Mysia, Anatolia died AD 216 ) who studied the homeostatic displacement following the onset of exercise were a major key to our current scientific breakthroughs. He stated the following:

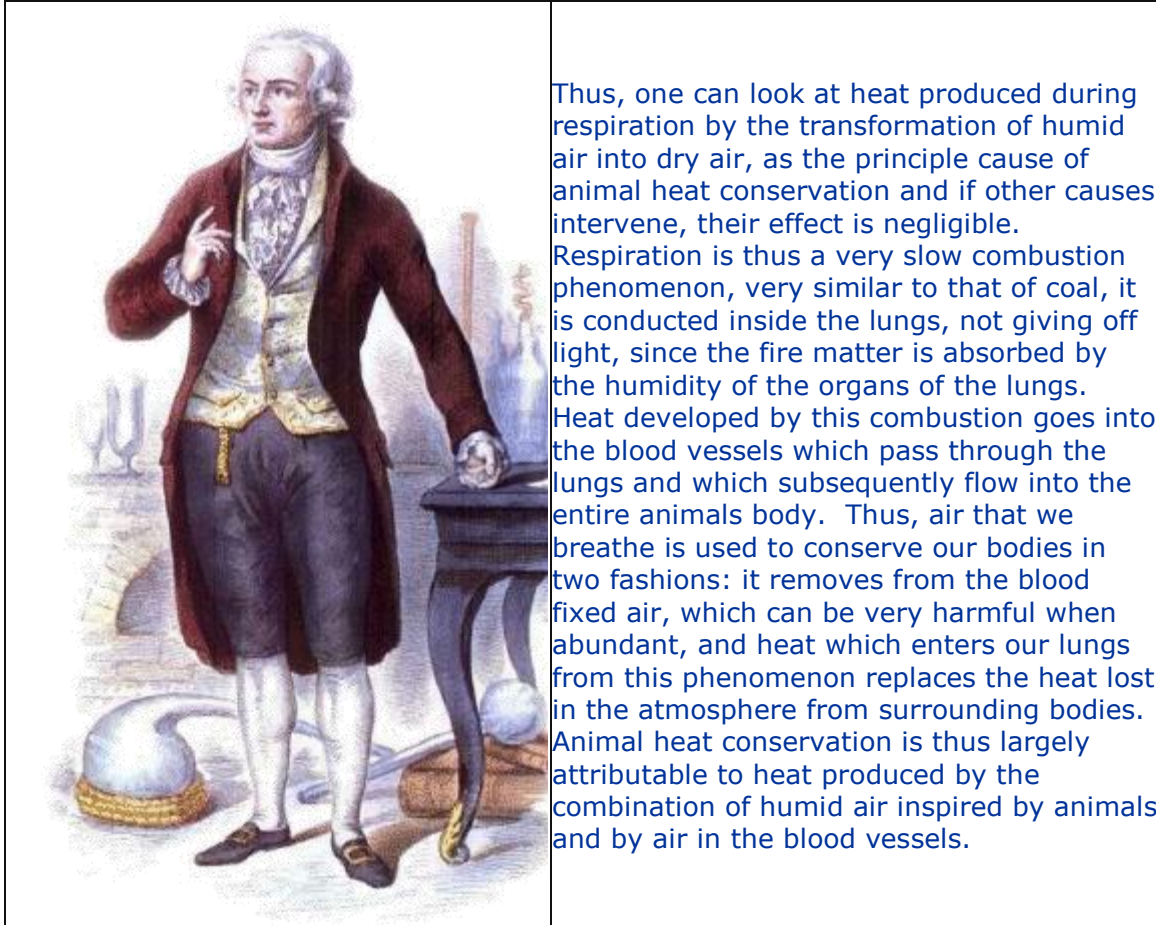
"To me it does not seem that all movement is exercise, but only when it is vigorous. But since vigor is relative, the same movement might be exercise for one and not for another. The criterion of vigorousness is change of respiration; those movements, which do not alter the respiration, are not called exercise. But if anyone is compelled by any movement to breathe more or less or faster, that movement becomes exercise for him (13)."

What Galen noted is of unspeakable importance. You see, the respiratory response, which was discussed, can and indeed is positively correlated to the field of exercise endocrinology. That is, at certain rates of one's  $\dot{V}O_2$  max, we can predict aspects of hormonal output, such as levels of both the catabolic hormone cortisol, and the anabolic peptide insulin. Antoine Laurent Lavoisier (1743-1794), undoubtedly one of the greatest scientists, was the first man we know of to quantitatively measure oxygen consumption during training.



**Seen above is a replica of Lavoisier's laboratory.**

In 1780, Lavoisier in 10 hours collected 3 grams of carbonic acid from a guinea pig breathing oxygen. In a further experiment, the subject was placed in a confined space with ice surrounding it. The outside of the space was walled off with ice so as to ensure the environment stayed the same temperature. However, the inner wall of frozen H<sub>2</sub>O melted due to the animal's heat expenditure. From this Antoine concluded:



From an exercise physiology standpoint, Lavoisier noted the drastic changes in heat production in varying states of stressful environments.

" The quantity of oxygen absorbed by a resting man at a temperature of 26 degrees C is 1200 pounces de France (approximately 24 liters). The quantity of oxygen required at a temperature of 12 degrees C rises to 1400 pounces. During the digestion of food the quantity of oxygen amounts to from 1800 to 1900 pounces. During exercise 4000 pounces and over may be the quantity of oxygen absorbed. "

I have always found his methods of experimentation fascinating. You can glean much from this work. For example, it is important to realize that the digestion of food is an extremely complex process, which requires additional energy expenditure as well as the release of specified chemical agents, which can either enhance or detract from your training session. The question therefore arises, when and what should one consume before, during, and after a workout? Should it be simplified nutrition, or complex? Is there a difference between what we consume 30 minutes before training, and 30 minutes into training? To understand such principles, you have no further to look than the complexities of maintaining equilibrium while under the gun (or rack).

During an intense bout of exercise, several notable factors take place. The nervous system controls the contractility of your muscles, your heart rate increases, sensory

neurons send pain signals to your central nervous system, the rate of respiration (oxygen is the terminal electron acceptor in aerobic cellular respiration; it is in the electron transport chain that most of our ATP is produced), and core temperature, as Lavoisier noted, increases. But there is far more than this. The rate at which substrates are catabolized increases exponentially, stored chemical energy is broken down at a frantic pace, damage to crucial cellular structures are inflicted, and repair is initiated. Moreover, most of this occurs irrespective of your conscious control! Scientists for years have slaved over the exact mechanisms responsible for the orchestration of such fantastically awe-inspiring events.

Much of this answer comes in the form of the neuro-endocrine system, which coordinates and directs the above actions. Further, it is a clear grasp of when and what chemical, or rather chemicals, do the orchestrating that will ultimately depict when and why you must consume the nutrients so vital to your recovery. For this reason, and this reason alone, I dedicate this article to: **Acute & Chronic Endocrine Responses To Exercise Induced Disruptions in Homeostasis.**

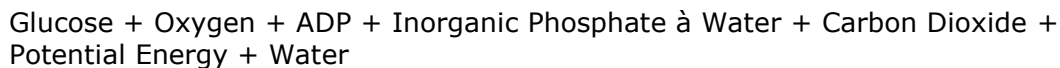
### **Exercise: What is it?**

We can define exercise as an acute muscular exertion or bodily effort, which, by its very nature requires a greater supply of energy as compared to a state of rest. That greater supply of energy is brought about by the body's physiological response to the exercise modality, which itself can be defined as a selected course of action - identified by the energy demand required to complete the said task. Note that the physiological response is contingent on several noteworthy variables. When I say variable, my reference is toward anything which is not constant, or that can change to meet or attempt to meet the demands of a given situation.

We need to magnify that last concept further while continuing on the ever-present theme of homeostasis. When doing so, it becomes so much clearer why the heart rate increases while training, how blood vessels dilate, and so much more! Now, take a look at a term known as a regulated variable. An RV can change due to external stimuli, but cannot exude its narrow limit before deleterious occurrences arise. One example of this is blood acidity levels. The Limit of pH is 7.35 to 7.45. A pH below 7.35 is known as acidosis. The body must be extremely precise in its regulation. Indeed, if the level of acidity falls to just 6.8 for even a moment, the cost is your life ( 14 )! During high-intensity training, the participant's need for oxygen increases. Aerobic Cellular Respiration can be defined as follows:



or



The process which was just outlined is one of the most complex series of reactions known. I could produce diagram after diagram on the enzymatic reactions alone, let alone what it is that influences them. The point, however, is that with increased oxygen and energy demand, comes an increased level of carbon dioxide. Carbon dioxide reacts with water to form a substance known as carbonic acid. Carbonic acid then dissipates a hydrogen ion. The greater the concentration of hydrogen ions in a solution, the greater is its acidity.

Athletes who train at extremely intense levels, such as in the sport of bodybuilding, must also deal with other sources of acidic invaders. For example, the body can extract energy from glucose without oxygen for a limited amount of time. This is known as anaerobic glycolysis. Glycolysis literally means the breakdown of glucose. In the presence of oxygen, this six carbon molecule is broken down to three-carbon backbone molecules known as pyruvate, which then enter an organelle known as mitochondria for further extraction of energy. When O<sub>2</sub> is not present, the end product of glycolysis is ATP, but also lactate or lactic acid, which, as the name indicates, increases the acidic environment.

This increase in acidity is dealt with immediately with a complex buffering system which permeates blood plasma. Think of this as your first line of defense. A second line is quite noticeable. You see, chemoreceptors are found all throughout the body. Chemoreceptors identify the chemical composition of a fluid. Such receptors found away from the brain's center of respiratory control are known as peripheral chemoreceptors. They can communicate with the brain by secreting their own chemical messenger to specialized, electrically active messenger cells known as neurons, which then relay the message to the mother system, or control center, known as the medulla or brain stem. If CO<sub>2</sub> levels rise, then the medulla gives the command to increase the rate at which you exhale (your rate of respiration). One experiment to test how sensitive the body is to CO<sub>2</sub> is to hyperventilate, and then to see how long you can hold your breath (note: do not do this while in water to win a contest! It's not a game to play with). Then compare this to how long you could hold your breath without hyperventilation. The former lowered overall CO<sub>2</sub> levels, which therefore lowered the stimuli for the need to breathe. The kidneys also control acidity through an extremely complex process which serves to pump H<sup>+</sup> ions out for disposal at an increased rate.

There are numerous regulatory variables in the body, and exercise pushes our ability to maintain them to the highest of degrees!

Two systems are ultimately responsible for the maintenance of your internal environment. These are the endocrine and nervous systems. Again, our focus today is on the former.

### **Cardio respiratory System / Thermo Balance during Exercise**

The following, describes how the body's CR system responds to training. I do this to clarify what actions the endocrine system supports.

- 1.** Airway resistance in the in the lungs must be decreased so as to facilitate transport of air into and out of the lungs. Accomplished via bronchial dilation (the diameter of your airways increases).
- 2.** Whilst training, the muscles' need for nutrients rises, as well as their need to transport wastes away (the metabolic byproducts of muscular contraction). Accomplished by increased cardiac output, which is a product of stroke volume (the amount of blood pumped per beat) multiplied by heart rate (beats per minute).
- 3.** Diversion of vital resources to supply high energy needs. Accomplished by lowering the diameter of blood vessels in lower energy regions such as the digestive tract, while simultaneously increasing the diameter of vessels surrounding the

working musculature. Note this has the effect of increasing resistance to the former, while decreasing resistance of blood flow to the latter. A nice analogy can be used by comparing your body to the Enterprise on Star Trek. When the ship is under attack, power is diverted to weaponry and shields; so too is blood flow diverted to working musculature, as well as to the increased oxygen demand placed on the lungs.

**4.** Lavoisier noted a heat increase in consumption of food, as well as with exercise. If the body is not able to control a heat influx, then various malfunctions such as heat stroke will occur. For more on this, see Venom's article on fluid intake. He addresses thermoregulation in depth, including concepts such as the basal metabolic rate and exercise induced thermogenesis. For now, realize that the body controls your temperature by directing blood to or away from the skin, as well as the control of sweat glands.

What does the endocrine system have to do with this? As you will see, the catecholamines epinephrine and nor-epinephrine reinforce the sympathetic nervous system in each of the above processes.

### **Metabolic System**

- 1.** To make fuel readily available for the synthesis of ATP, which itself is needed for contractile activity. Accomplished by stimulating the catabolism of glycogen to glucose, as well as the mobilization of fatty acids. Moreover, the mobilization of amino acids for a process known as gluconeogenesis (the creation of glucose from a non glucose substance) is stimulated.
- 2.** To assure that blood glucose levels are maintained in a steady state to feed working muscles, as well as the nervous system, which depends on glucose.

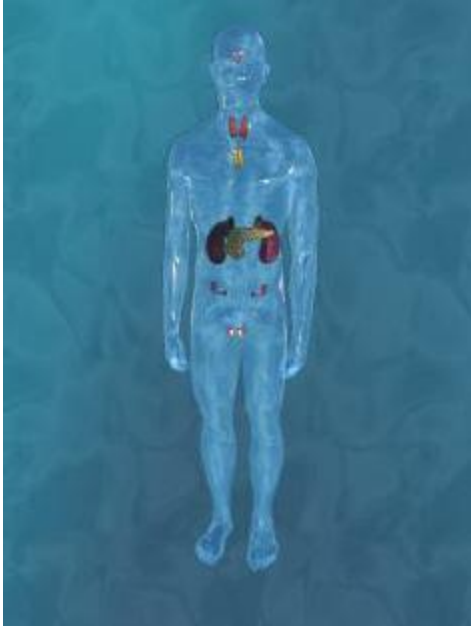
Metabolic hormones include: insulin, glucagon, cortisol, growth hormone, t-3, as well as the catecholamines.

Note: The field of study which deals with energy transference is known as bioenergetics and will be covered like never before right here on ABC in the near future!

### **Fluid Regulation**

See Venom's article on Thermoregulation

### **Chemical Communication under the Microscope**



A chemical messenger is a ligand, which itself is defined as a "molecule which can bind reversibly to a protein (14). It is fascinating to note that the word hormone has its roots in the Greek language, in which case it can be properly translated: "to arouse activity (15)." At a time it was believed that hormones were purely synthesized by one organ and then subsequently transported via the circulatory system to eventually affect a different tissue. Daryl K. Granner states that this original description is too restrictive, because hormones can act on adjacent cells (i.e. paracrine action) and on the cell in which they were synthesized (i.e. autocrine action without entering circulation) (15). We can therefore say that a hormone is a chemical messenger which is secreted (a process of release) and that acts on a target cell, that is, a cell which contains specific receptor sites which have an affinity, can bind to, interact, or recognize that which was secreted. So efficient is this God-designed system that it has the capacity to link over 75 trillion cells with incredible precision!

### **Basic Classes of Hormones**

**1. Steroid Derived Hormones** – These hormones are synthesized from cholesterol. Cholesterol is lipophilic, which means that it can readily mix with fat. Interestingly enough, this four ring molecule plays an integral part in cell membrane function as well as in the digestive tract via bile salts (14, 38). Because they are lipophilic, they readily cross the cell membrane, which is lipid dominated. Once inside, they migrate to either nuclear or cytoplasmic receptors (29). Recall that every cell contains a nucleus, which is the control center of that complex. (1) The steroid hormone crosses the cell membrane and binds to a nuclear receptor forming a complex, which then migrates into the control center. (2) Once inside, the complex binds to what is known as the "hormone response element (14)," effectively activating or deactivating a gene. (3) The information in the gene is transcribed or placed onto what is known as messenger ribonucleic acid, or mRNA (29). (4) Finally, the mRNA moves to the cytoplasm of the cell (the cellular environment where it is translated into a specific protein by intracellular machinery known as the ribosome).

These synthesizing factories are extremely complex, and studies show that they adapt wonderfully to damaged regions. Indeed, Stephen Welle and A. Chesley et al. showed that ribosomes actually increase their regional specificity in response to areas being degraded by exercise (7, 40), that is, the cellular machinery responsible for protein synthesis increases the rate at which it synthesizes proteins in the areas which need attention. In fact, Dr. Horne and colleagues stated their results indicate that "increased association of ribosomes with the myofibrils occurs during muscular hypertrophy (18)."

In regards to hormonally influenced changes in optimal recovery, Kramer and some of the worlds top scientists assert that: "Clearly, heavy-resistance exercise disrupts or damages certain muscle fibers that later must undergo a remodeling repair process. Dietary nutrients, hormones, and growth factors interact to regulate this remodeling of skeletal muscle proteins.... to enhance the development of muscular strength and size with heavy-resistance training, optimal conditions for recovery from the individual exercise training sessions are necessary. Recovery involves the coordinated functioning of several physiological processes that are heavily influenced by the **availability and actions of specific hormones and nutrients** (52). " Note the aspect which I bolded. These scientists stated that a large part of whether or not you recover is the availability of various hormones. I would add that the availability of other hormones, such as those which linger following an insufficient( strawberries and cream ) post-workout refill, can enhance unneeded catabolic processes. The opposite of what you want!

**2. Amino Acid Based** – These are lipid insoluble hormones. As such, they find their receptors on the cell membrane and act through a secondary messenger system (15, 29 ). For the purposes of this article, I will provide an outline of the cAMP system (28, 29): (1) The lipid insoluble hormone binds to its respective cellular receptor site. First messenger initiation has begun. (2) A membrane protein known as a G-Protein is activated, which subsequently activates Adenyl Cyclase, an enzyme which causes the catabolism of ATP into cAMP (the c stands for cyclic), which acts as a second messenger. (3) Cyclic AMP activates a Protein Kinase enzyme. Note that it is extremely common to have enzymes in a cell in their inactive state. One of the more common ways of activating or inactivating an enzyme is through a process known as phosphorylation, that is, the process of adding a phosphate group to the target molecule or detaching it from that same molecule (de-phosphorylation ). (4) The Protein Kinase then activates specific enzymes in the cell.

**Quick Question:** Why would calcium channels cause such a rapid response in the cell? Answer below.

The above two paragraphs cannot be understated! In fact, in this post-workout series, you will find that we can actually mimic hormones such as insulin through differing pathways; furthermore, these pathways can act synergistically with insulin to enhance glucose uptake and glycogen restoration. It is for this reason that an understanding of this vital system is a must for all serious athletes. Your understanding of bodily mechanisms and what they control will have a direct correlation to your ability to manipulate those mechanisms for the optimization of anabolism.

**Answer:** The body uses calcium as a messenger for several functions. For example, it is the key to muscular contraction. It is regulated by a process known as primary

active transport. Literal pumps are found on the cell membrane that pump calcium against their concentration gradient into the EFC and out of the ICF. These reserves are known as smooth endoplasmic reticulum, and in a muscle cell they are denoted the "sarcoplasmic reticulum ( 50 )." Binding sites in the cell are specific for  $Ca^{++}$ , and by controlling their release you can efficiently control cellular actions. From a more direct standpoint, calcium concentration inside the cell is only 100-200 **nano**Moles, whereas in the extra cellular fluid it is approximately 1.2 **milli**Moles. Put in clearer terms, the ECF has a concentration of 5, 000 to 10, 000 fold above the ICF (15)! Calcium is also charged, which means that it can be used to conduct an electrical current rapidly. The rapid influx is of course due to its concentration gradient, and electrical gradient. The intracellular environment is negative relative to the ECF. Thus, calcium will fly faster into the cell than a bullet out of gun! We will cover calcium mediated hormonal stimuli even further in a very near issue.

### Endocrine Stimuli

Several factors determine the amount of a specific hormone in the blood stream at any one time. The following will outline such factors (15, 38, 14, 29).

- A.** The amount of hormone produced in a particular gland.
- B.** The rate of secretion.
- C.** How quickly the hormone is degraded once it has journeyed into blood plasma.
- D.** If the hormone relies on a transport protein, such as albumen, what is the concentration of these carriers?  
This also has a bearing on how much of the hormone is active or not active. In other words, though much of the hormone is in the blood, much of it will be inactive when bound to the transport protein, until it is released for migration into a specific cell. Hormones which travel in the blood bound to carrier proteins include the hydrophobic steroid class (hydro = water, phobic = fearful).

Realize that a gland secretes a hormone in response to chemical stimuli, which can be neural, hormonal, or humeral (1). In neural activation, a neuron acts directly on the target gland to stimulate secretion of its particular chemical messenger.

This brings up another point. Chemical messengers secreted by neurons are in cases also found in endocrine glands. The secretion of the catecholamine norepinephrine stimulates the adrenal medulla to secrete both norepinephrine and epinephrine!

(2) Our second option concerned hormonal activation. When a hormone stimulates the release of another hormone, it is called a trophic hormone. The hypothalamus is infamous for this very aspect of its function. It releases growth hormone releasing hormone, which stimulates the secretion of GH from the anterior pituitary, as well as a vast number of other releasing factors.

(3) Humeral activation is associated with fluids in the body, in particular the blood. Nutrients carried in by the blood affect hormonal secretion here. For example, aldosterone is responsible for the secretion of potassium (it secretes it for elimination from the body). There is a condition known as HyperKalemia in which  $K^+$  levels rise to a level above normal concentrations. The results can actually lead to death! An

increase in aldosterone increases secretion of K<sup>+</sup>, and therefore an increase in K<sup>+</sup> leads to an increase in aldosterone secretion. Walcott et al. states that, "increases of plasma potassium directly stimulate aldosterone secretion. This effect of potassium on aldosterone serves as a protective mechanism against the development of hyperkalemia (51)." Conversely, when sodium is in excess, aldosterone and renin are suppressed (41). This is because aldosterone acts to retain sodium. Higher levels of this electrolyte would lower the need for higher concentrations of this hormone. Dr. Rasmussen and colleagues increased the sodium intake of eight individuals. They found that, "Significant natriuresis occurred within 1 h (48)." Natriuresis is defined as a high level of sodium excretion by the body. Why did this occur? Check it out: "A 6-fold increase was found during the last hour of infusion as plasma renin activity, angiotensin II (ANGII) and aldosterone decreased markedly. Sodium excretion continued to increase after **NaLoading**."

In essence, the endocrine system works through a "closed loop feedback mechanism." It can be summarized as follows (19):

- Organ X secretes a trophic hormone, which stimulates organ Y to secrete a specific hormone, which in turn inhibits the release of the trophic hormone from Organ X.
- Nutrient X decreases, Gland Y is stimulated to secrete a chemical substance which stimulates the release of stored X. Nutrient X increases, and inhibits secretion from Gland Y.

Of course the process goes through endless combinations, and numerous hormones regulate these processes, but the above is a general idea of what a closed loop feedback mechanism is. As you will see, other actions such as agonistic/antagonistic relationships also play a major role.

### The Cellular Response

We have already discussed direct gene activation, as well as secondary messenger systems. The mechanisms by which a cellular response occurs depends on blood concentration (factors discussed above), the affinity that the receptor has for the ligand and, finally, the number of concentration or quantity of receptors on a cell.

When the concentration of a hormone increases, the cellular response increases like so (14):

Hormone + Receptor → Hormone-Receptor Complex → Cellular Response

β

As pictured by the arrows, this is a reversible action. Recall that a ligand can both bind and unbind, which is why affinity affects the response (see below). As the concentration of the hormone increases, the reaction is driven to the right. When all the receptors are bound to by hormones, a state of 100 percent saturation is reached.

Receptor activity is influenced in great part by hormones themselves.

Up regulation – Receptor density refers to their respective concentration on a cell membrane, cytoplasm or nucleus. The greater their number, the more likely a

hormone will bind. Think of it as an architect putting more parking spaces in their lot so that more cars can fit. Up regulation occurs when the body adapts to a specific environment by increasing the number of receptors on a cell. There are two ways of accomplishing this. First, when a body faces low levels of a specific hormone for an extended period of time, it then up regulates such that even at a lower concentration, it can have a significant effect. Exercise can increase the sensitivity of hormone receptors as well. In other cases, however, it has been shown that an increase in a specific hormone can increase the level of receptors. In cats, an increase in exogenous estrogen unregulated receptors has been shown (39).

Down Regulation – We have the opposite of UR here. Ming Tsai and colleagues state that after one hour of progesterone, receptor sites in rabbits lowered (39).

Disabling – Another action which appears when the binding of a particular hormone disables the receptor.

### **Catecholamines Responses to Exercise**

Catecholamines are ultimately derived from the amino acid tyrosine. In catecholamine synthesis, one catecholamine serves as a precursor to the next catecholamine in a sequence-like fashion.

Note how dopamine acts as a precursor to norepinephrine, while NE subsequently becomes the precursor to epinephrine. This is called a chemical pathway. We must note that, ultimately, it is the enzymes contained within a cell that determine how long this chemical pathway will last. For example, if a cell secretes the hormone dopamine, it lacks the enzyme that catalyzes the reaction, which would morph it to NE. Dopamine is the precursor for each of the other catecholamines, and is therefore contained in all catecholamine-secreting cells (14).

What is fascinating to note is that both the nervous system and endocrine system secrete epinephrine (also known as adrenaline) and norepinephrine (or noradrenaline). However, NE is the prominent neurotransmitter (chemical released from a neuron) released by sympathetic peripheral (see notes) neurons, while epinephrine is the dominant hormone secreted by chromaffin cells in the adrenal medulla (51) and plays a role in central nervous system stimulation. The adrenal glands are composed of the outer cortex, and an inner core called the medulla. The word chromaffin is a term reflecting the fact that within these cells are granules, which turn brown when treated with certain oxidizing agents for histological analysis (16). Epinephrine is known as the dominant hormone of the adrenal medulla because it accounts for 80 percent of secretion in this region, while norepinephrine accounts for 20 percent.

**Note:** The Central Nervous system includes the brain and spinal cord; the nerves which branch off of this run to effectors: organs/cells. The sympathetic nervous system in physiological terms is known as the fight or flight system. However, in anatomical terms it is referred to as the thoracolumbar nervous system, as nerves which serve this function branch out of the thoracic and lumbar regions.

There are a few principles, which you need to understand:

1. Under Normal circumstances, the parasympathetic nervous system dominates over the flight or fight.

When at rest, most of the energy needed for muscular contraction occurs in the viscera, that is, the organs responsible for digestion. Internal organs operate off of smooth muscle, which is not under your control.

2. The sympathetic nervous system reacts faster than the endocrine system. Therefore, an athlete will see a quicker rise in norepinephrine than epinephrine in response to exercise, as is explained below.

3. The brain regulates both branches of the autonomic NT. It does so using several mechanisms, primarily reflexive arcs. For example, when you stand, gravity pulls blood to your lower extremities. This has the effect of lowering venous return of blood to the heart. As a consequence, blood pressure receptors relay signals to the medulla oblongata (your cardio respiratory center in your brain). The medulla then increases sympathetic output, which increases the heart's cardiac output, and before you even knew there was a situation, BP is back to normal! Other structures in the brain, such as the hypothalamus, regulate plasma levels as well as temperature (See Venom's article - [Effect of Plasma Volume on Myofibril Hydration, Nutrient Delivery, and Athletic Performance](#)). Therefore, an increase in temperature, which occurs during training, would send signals to the hypothalamus, which would make the necessary changes. The cerebral cortex, as well as the limbic system, also sends signals to these regions. The former is our area of consciousness (immediate thoughts and perceptions, what you are currently aware of, the opposite of subconscious), while the latter is concerned with emotions. When you get angry, the heart rate increases rapidly, due to increased sympathetic nervous system activity, as well as decreased parasympathetic activity (known anatomically as the cranio-sacral nervous system and physiologically as the rest and digest system). Note that these hormones act extremely quickly, while their actions dissipate quickly, unlike the steroid hormones.

4. Adrenaline and Noradrenaline can **1.** Act to inhibit activity X at organ A **2.** Act to increase activity X at organ B (explained after "5")

5. Both neurotransmitters/hormones (depending on whether they are secreted by neurons or the adrenal medulla respectively) have higher affinities at varying sites. However, they both can bind to the same receptors sites. The actual difference occurs in affinity for that receptor, not the response. Thus, they act as agonists for a common cause (fight or flight optimization).

To understand four through five, we need to take a look at adrenergic receptors (receptors with an affinity for adrenalene/noradrenalene). During a fight or flight response, you need optimal energy for muscular contraction. This entails increasing cardiac output (again, the amount of blood pumped throughout circulation per minute), increased blood flow to skeletal muscles, and decreased blood flow to the digestive tract, as well as most other organs relative to the working muscles. This is accomplished by:

A. Vasoconstriction – To constrict blood vessels surrounding a particular region, thereby restricting blood flow.

B. Vasodilation – To relax smooth muscle in blood vessels surrounding a particular

region, thereby increasing blood flow.

How is it that E and NE can constrict blood vessels in one organ while simultaneously dilating blood vessels in another? The answer was found in 1948 when a scientist by the name of Ahlquist introduced the concept of alpha and beta adrenergic receptors to explain these contrasting effects (2). You see, the smooth muscle in blood vessels throughout the body contain both of these receptors. The alpha receptors stimulate vasoconstriction, and subsequently decrease blood flow, while beta receptors stimulate the dilation of blood vessels, and with it comes an increase in blood flow to the organs they innervate (supply with blood) (53). In the majority of regions throughout the body, the concentration of alpha receptors is higher. Thus, when catecholamine concentration increases, blood is diverted away from the majority of regions. However, beta receptors are dominant in both cardiac and skeletal muscle blood vessels, which means blood is diverted toward these structures.

**Note:** The above is only a partial view of receptor-mediated actions and makes this concept easier to comprehend; however, it appears to be more complex. For example, if you are working your calves, you need vasodilatation to occur there and not in other non-working musculature. The control mechanisms for this will be described under the alpha 1 subsection.

The concept of adrenergic receptors becomes more complex. Nearly 20 years after Ahlquist's findings, a group of scientists led by Dr. Lands observed that enhanced cardiac activity and vasodilation were signaled by the binding of differing structural receptors. Thus, they denoted receptors responsible for cardiac effects as beta 1 receptors, while the latter were denoted beta 2 receptors. Such a discovery prompted Langer et al. to discover an alpha 2 receptor which was structurally distinguished from alpha one receptors in pre-synaptic nerve terminals. Simply put, this means that they are used to regulate the release of post synaptic neurons which are responsible for the release of NE. As you will see, alpha 2 receptors have fascinating properties! In fact, discoveries have changed thought patterns on these receptors, in that they have actually been found to be located in vascular smooth muscle (12).

### **Alpha One Receptors** – Cellular Actions Caused When Bound To:

Alpha one receptors first bind to the extra cellular membrane. The formation of a complex (ligand to receptor) stimulates a G-protein to activate an enzyme known as phospholipase C, which in turn speeds the reaction which changes a molecule known as PIP2 (phosphatidyl inositol biphosphate) to IP3 (inositol triphosphate and DAG (diacylglycerol). IP3 goes on to initiate the release of intracellular Ca<sup>++</sup> (calcium) stores which then initiates a specific response in the cell. DAG activates a protein kinase C, which also initiates a response in the cell. In summary:

Epinephrine + Alpha 1 receptor → Epinephrine-Alpha 1 receptor complex → Stimulation of G Protein → Activation of phospholipase C → Catalyzed reaction of PIP2 to IP3 and DAG:

IP3 → Initiation of intracellular release of Ca<sup>++</sup>

DAG → Activation of protein kinase C for initiation of cellular response

Smooth muscle is found in blood vessels, as well as viscera. Consider a blood vessel as an adaptable tube. Inside of this vessel is a lumen (hollowed out interior), which is lined by endothelium. Endothelium is a lining tissue which is extremely slippery, so as to discriminate against clogging. Just deep to that is a layer of smooth muscle, whose stimulation is regulated by the calcium calmodulin system. For an overview of how a muscle is initiated to contract, I would suggest reading the article on the [All or None Principle](#). Muscular contraction, be it smooth, cardiac, or skeletal, is dependent on  $Ca^{++}$  intracellular concentrations. In skeletal muscle tissue, a structure known as the troponin-tropomyosin complex disallows myosin cross bridges to be formed with actin binding sites. Calcium disables the T-T complex's disabling abilities, and cross bridges are able to form. In smooth muscle, an enzyme known as myosin kinase initiates the phosphorylation of myosin cross bridges (in other words, this enzyme is needed for cross bridge formation, and thus contraction of smooth muscle). As seen above, IP3 initiates the intracellular release of  $Ca^{++}$ , which in turn activates calmodulin, which in turn activates myosin kinase and ultimately smooth muscle contraction (53).

We discussed in the previous notes that a mechanism needs to be in place to further optimize blood flow to working muscles. Though alpha 1 receptors are reportedly less abundant in skeletal muscle, they are still present, and their responsiveness would need to be attenuated during exercise. Blood must be drawn away from inactive tissues and toward active tissues.

It is interesting to note that alpha 2 receptors also are involved in vasoconstriction near skeletal muscle. Studies show that acidosis, hypoxia, and ischemia (natural occurrences of a working muscle) each have inhibitory effects on alpha 2 receptors, but not alpha 1 receptors (35, 36, 37, 47).

Results show that the vasoconstrictive effects of E and NE are inversely proportional to exercise intensity. That is, "that the magnitude of vasoconstriction decreases as exercise intensity increases (22)." At high enough intensities, alpha 1 receptors are also inhibited (22, 6). When you think about this from a design standpoint, it makes perfect sense. Alpha 2 receptors' ability to bind with catecholamines decreases with less intensity than alpha 1 receptors, but as the intensity increases, alpha 1 also loses its sensitivity; I liken this to two thresholds. Thus, if several muscle groups are working, those which have the highest metabolic needs will be accommodated accordingly, and those which have lower but still higher than resting needs will also be appropriately accommodated. Some have postulated that such an occurrence is due to increased blood flow (i.e. as blood flow goes up, alpha receptors' response goes down). However, studies do not back this hypothesis up; in fact they, conflict with it (6). Muscular contraction is also put forth as a postulation. G.D. Thomas and colleagues support in their study on BF by reporting that, "the increased muscle blood flow resulting from a combination of impaired vasoconstriction and increased arterial pressure was paralleled by increased force of gastrocnemius-plantaris muscle contraction (17)."

What also must be understood is that metabolic byproducts of muscular contraction also directly stimulate vasodilation, which opposes effects of alpha receptors. Delp MD and Laughlin MH explain: "The primary determinant of muscle perfusion during sustained exercise is the metabolic rate of the muscle. Metabolites from contracting muscle diffuse to resistance arterioles and act directly to induce vasodilation, or indirectly to inhibit noradrenaline release from sympathetic nerve endings and oppose alpha-adrenoreceptor-mediated vasoconstriction (11)" From the italic

portion of the aforementioned quote, one can also see that metabolites from skeletal muscle are also postulated as a factor which actually inhibits the sympathetic nervous system from releasing the initial stimulus for vasoconstriction. Such a mechanism is also supported by other respected authorities (5).

Binding to alpha 1 receptors also has notable metabolic aspects such as lipolysis, or the breakdown of fats. When training, fats become a valuable resource, and their liberation into the blood stream markedly increases their usability. In one study, Flechtner-Mors et al. performed a study to test alpha 1 receptor initiation, as compared to alpha 1, alpha 2, and beta receptor binding (34). To accomplish the alpha1 increase, a1 agonist called norfenefrine was used, whereas norepinephrine, which binds to the three sites mentioned, was incorporated for the comparison group. Finally, an antagonist to alpha 1 receptors was included, which is known as urapidil. Thirty-eight women were broken up into three groups and received either the a1,a2,b agonist norepinephrine, the a1 agonist norfenefrine, and the a1 antagonist (opposes the action of catecholamine binding to the receptor site). It was found that:

**“Both norepinephrine and norfenefrine caused a significant elevation of glycerol level** over time (one-way ANOVA for repeated measurement:  $F = 18.8$ ,  $p < 0.001$ ,  $F = 11.3$ ,  $p < 0.001$ , respectively), whereas the addition of urapidil had little effect on glycerol outflow ( $F = 1.1$ ,  $p = 0.396$ ). The kinetic profiles of glycerol concentration in the presence of norfenefrine and norepinephrine were similar.”

To realize the significance of this, it would help to review the chemistry of a triglyceride. The point is that one can measure the lipolytic effects of a process by measuring extra cellular fluid levels of glycerol, a soluble byproduct of fat catabolism. They add, “Investigation of the effects of 1-adrenoceptor agents on adipose tissue lipolysis is warranted to determine their possible role as therapeutic agents in obese subjects with the metabolic syndrome.” Of course, as we will see, epinephrine naturally rises with specific training protocols, which will burn a notable amount of fat. Alpha 1 mechanisms for fat use are still unknown, but are thought to be linked to their stimulation of cAMP.

Various studies also show that epinephrine increases glucose levels via increased glycogenolysis in the muscle tissue and gluconeogenic activity in the liver, as well as increased glycogenolytic (8, 42, 44, 9). The latter refers to the synthesis of glucose via non glucose substrates such as amino acids, while the former refers to the breakdown of glycogen to glucose for either release of fuel into the blood stream, or direct use by muscle tissue. Studies show that 1. Alpha 1 and beta 2 receptors dominate in the liver, and that 2. These are the receptors responsible for glycogenolysis in the respective organ (9, 26). It is interesting to note that Chang et al. found that hepatic (of the liver) glycogenolysis was mediated via alpha receptors by norepinephrine, while epinephrine had a more dominant effect on beta 2 receptors (see affinity section above to understand why).

Thus, in general, alpha 1 receptors increase blood pressure, lower blood flow to inactive tissue, stimulate the release of glucose into the blood stream, as well as glycogen breakdown in muscle tissue, and increase the breakdown of fatty acids.

## Alpha 2 Receptors

Alpha receptors mediate their actions through G-proteins. The subtype discussed above increases intracellular calcium levels, as well as protein Kinase C. Alpha subtype two activates an inhibitory G protein (denoted G), which diminishes the activity of cAMP (it does so by inhibiting adenylate cyclase which activates cAMP) (3). Many fascinating studies have searched for the implications of this. First, it is well established that alpha one receptors in the CNS act to actually inhibit NE release(53). Skoglund et al. realized that both subtypes of adrenergic receptors were found on the pancreas. Moreover, it is known that adrenaline suppresses insulin secretion during exercise, which has great significance. Insulin stimulates the formation of glycogen, and mediates the storage of glucose. While training, the breakdown of glucose is desired, as well as its liberation for active tissue use. Here is an outline of their study (43):

**Purpose:** "Stimulation of alpha-adrenoceptors is known to inhibit insulin secretion under a variety of conditions. In this study, the question of whether these alpha-adrenoceptors are of the alpha 1- or the alpha 2-subtype was investigated."

**Methods:** As with studies portrayed above, agonists, or ligands, which mimic the action of catecholamines for the particular receptor were used. In this study the alpha 2 agonist clonidine was used, as well as phenylephrine for the alpha 1 agonist. Antagonists were also used, which include Yohimbe for alpha 2 receptors, and prazosin for alpha 1 receptors.

**Results:** "The selective alpha 2-adrenoceptor agonist clonidine (0.05-50 nmol/kg) was found to markedly inhibit the insulin secretory response to both glucose and the cholinergic agonist carbachol. This inhibition of insulin secretion was counteracted by the alpha 2-adrenoceptor antagonist yohimbine (2.6 mumol/kg), but not by the alpha 1-adrenoceptor antagonist prazosin (2.6 mumol/kg)."

In other words, the stimulation of alpha 2 receptors had an inhibitory effect on the secretion of insulin from the pancreatic islets of langerhans, namely the B cells; whereas, "In contrast, the alpha 1-adrenoceptor agonist phenylephrine (0.05-50 nmol/kg) did not affect the insulin secretory response to either glucose or carbachol."

What is also interesting is that both alpha 1 and 2 receptors show a direct relationship with enhanced glucagon levels. The same team of scientists above (Skoglund G, Lundquist I, Ahren B.) teamed up again in the European Journal of Pharmacology to examine this relationship. As stated, clonidine and phenylephrine are alpha 2 and 1 agonists, respectively. When injecting these into the participants, it was found that, "both phenylephrine and clonidine enhanced the plasma glucagon levels. The peak level of plasma glucagon was seen at 2 min after clonidine injection whereas phenylephrine enhanced the plasma glucagon levels throughout a 10 min period after the injection... We conclude that both alpha 1- and alpha 2-adrenoceptor activation enhances plasma glucagon levels...and that alpha 2- but not alpha 1-adrenoceptor activation lowers plasma insulin levels (45)."

One opposition that is beginning to be seriously studied is the fact that alpha 2 receptors inhibit fat breakdown, thus opposing alpha 1 receptors. This may serve as a check and balance system. Catecholamines are perhaps what are mainly responsible (directly and indirectly) for fat burning while training (30). I feel one of the more thorough studies backing a2 as an antagonist to lipolytic activity is found in the Journal of American Physiology and was conducted by Vladimir Stich and his

fellow scientists (49).

Using agonists and antagonists they found that, "epinephrine contributes to exercise-induced lipolysis, although the existence of 2-AR-mediated counteraction was clearly revealed with our protocol." Such results were found when "glycerol output in subcutaneous AT was enhanced by the blockade of -AR by phentolamine."

In their study, even though alpha 2 receptors did lower lipolysis, when they were not blocked, at higher concentrations of epinephrine, the rate of fat burning was higher. That is, there is a direct relationship between epinephrine levels and lipolysis. This was demonstrated by Mauriege et al. in the European Journal of Clinical Investigation. These scientists make the following vital statement: "Epinephrine always has a higher affinity for alpha-2 sites than for beta sites in the subcutaneous and omental deposits. In lipolysis studies, epinephrine, in the absence of adenosine in the incubation medium, initiated an anti-lipolytic effect in femoral fat cells and promoted inhibition of lipolysis at lower concentrations in abdominal subcutaneous fat cells, the effect being reversed at higher doses; epinephrine, however, was always lipolytic in omental adipocytes."

Recall from above when I emphasized that a receptor response is due to not only affinity but concentration levels. It would seem that at lower concentrations, epinephrine's anti-fat-burning effects are manifested on its higher affinity sites, but at higher concentrations, the binding to beta receptors overcomes this effect. That is, beta-epinephrine receptor complexes are highly dependent on concentration, and this is manifested in the reversal of effects. Exercise protocols which increase concentration levels of catecholamines will therefore optimize lipolysis. Such findings are also of interest to treating obesity, in that it is postulated that leaner people have a lower concentration of alpha 2 receptors than the obese (49).

## Beta 1 Receptors

You are driving when all of a sudden a car cuts in front of you such that you immediately apply pressure to the breaks. Right away you notice your heart rate has increased. Enter beta 1 receptors. These amazing contraptions have binding sites for NE and E, whose connectivity initiates a stimulatory G-protein. The heart itself is stimulated to contract via electrical impulses. That is, positively charged ions which include sodium (Na<sup>+</sup>) and Calcium (Ca<sup>++</sup>) are higher in the ECF (extra cellular fluid) than the intracellular. When channels open up, they come rushing in, as the positive charge flows to the more negative interior of the cell an electric current is generated, which stimulates muscular contraction in a similar manner to skeletal muscle contraction (see All or None article). The stimulatory G-protein activates cAMP, which has a twofold effect, in that it increases the rate at which sodium enters the cell, and activates a protein kinase, which phosphorylates calcium ion channels. This has the effect of increases in intracellular calcium.

**Note:** An allosteric reaction is one which causes a protein to change its shape or conformation. As has been discussed, the binding of a phosphate group can cause such an allosteric reaction, such that an ion channel, which previously could not bind to a certain ion for transport, can now bind to that ion.

Note also that the heart is run by a pace maker. A machine so wonderfully designed that it will blow your mind. Fortunately, it is a subject that is near and dear to my heart (no pun intended). As such, I will present much of my research to you on the subject as we delve further into the world of cardiovascular conditioning!

In summary, the heart is stimulated to contract when an action potential or electrical current is conducted across the gap junctions in the myocardium. NE and E increase the rate of electrical impulses, and therefore increase the rate of contraction. Note that the sympathetic nervous system is responsible for the immediate raise in heart rate. Epinephrine takes longer to be released from the adrenal medulla and must travel to the heart via the blood stream. NE is directly released to the heart, a clear example of how fast-acting fight or flight technology truly is! Increased heart rate again is directly proportional to cardiac output. More blood is circulated, oxygen is delivered at a more expedient rate, nutrients are brought to working tissue, and CO<sub>2</sub> is carried away for expulsion at a more rampant rate.

It is also important to note that Beta 1 and Beta 2 receptors have positive effects on increasing the rate of lipolysis (10, 31).

### **Beta 2 Receptors**

Beta 2 receptors activate a G protein, which then activates cAMP also. However, this receptor serves to inhibit muscular contraction, which causes vasodilation (16), especially in the region of skeletal muscle, and smooth muscle in the bronchioles which serve to conduct air into and out of the lungs (if they are dilated, air flow will be increased much like blood flow is increased in dilated blood vessels).

### **Beta 3 Receptors**

These play an assisting or weaker role in catecholamine fat mobilization (they work through g-proteins as before) (32, 33).

### **Overall Control of Receptors**

NE is the main sympathetic neurotransmitter, while E is the main fight or flight adrenal hormone. They control sites due to affinity, and of course concentration. The following information describes the affinity each receptor has in a comparative manner(14, 16):

- a1: NE has a greater affinity than E
- a2: Same as above
- b1: Both are equal
- b2: E has a much, much greater affinity than NE
- b3: Both are equal

### **Hormonal Response during Exercise**

In order to understand the following section, I need to reemphasize that NE is the primary neurotransmitter of the sympathetic nervous system, whereas E is the primary hormone of the adrenal medulla. Thus, you should expect NE to rise more rapidly than E. The latter's job is to elongate and enhance sympathetic effects. Also recall that NE is also secreted by the adrenal medulla, but in lower amounts.

### **Catecholamine Response to Various Levels of VO<sub>2</sub> Max.**

Dr. Galba has contributed greatly to our understanding of endogenous hormone secretion in response to various exercise patterns. We will review some of his studies which are based on percentage V02 Max. Maximal Oxygen uptake is just that: the highest amount of O2 a person can consume and use to produce adenosine triphosphate aerobically during strenuous exertion. For example, there is a correlation between the Borg scale and VO2 max. At rest, which would correspond to a 1, you are using approximately 10 percent of your V02 max, moderate effort would be approximately 50 percent, fairly hard would be approximately 70 percent, while extremely hard, or a 10 in your observed exertion, would be 100 percent V02 max.

Galbo et al. tested graded and prolonged exercise to see what their effects were on catecholamine concentration in the blood plasma. Graded simply means at various levels of maximal O2 intake.

Experiment (20) – Eight men ran on a treadmill at three levels of V02 max. The first is labeled as mild, or 44 percent, the second was 75 percent or moderate, while the last reached 100 percent maximal oxygen uptake. Runs lasted for 10 minutes, with the exception of the max outing. After 10 minutes of 75 percent V02 max here, participants increased the pace of the run every 25 seconds, and reached their max in 4-5 extra minutes. I have placed the results in graphical form below (shown in nanograms per millileter of plasma).



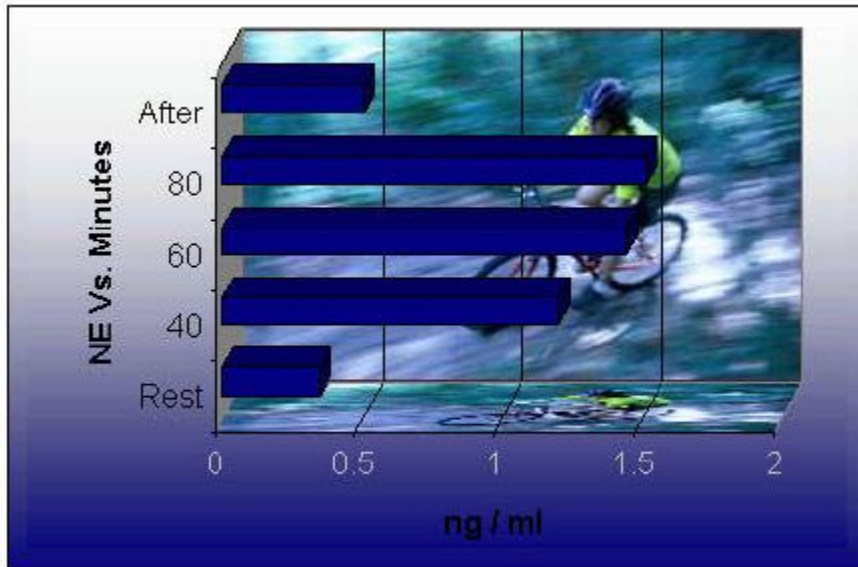
At rest and at mild oxygen consumption, epinephrine levels were at .07 (+ 0.01) ng/ml. At mild V02 the levels were at .12 (+ 0.02), and finally, at heavy, exertion levels rose to .46 (+ 0.03), which is well over 6 times resting amounts! From this we see that epinephrine levels are intensity dependent, and do not begin to rise until after 75 percent V02 max. After 75 percent, levels rise exponentially. Note that statistical significance was reached at the .0025 level ( $P < .0025$ ).



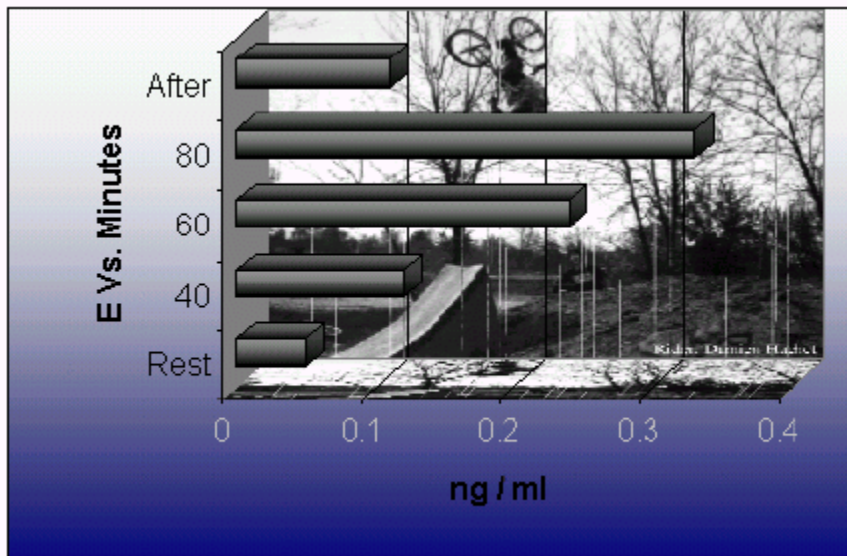
From this graph, you note a similar pattern (rest = .40, mild = .44, moderate = 1.30, heavy = 2.22, and rest is back down to .46). The main difference is that moderate exercise showed a markedly larger increase in NE, relatively speaking, than E. Again, we can attribute this to the fact that the sympathetic nervous system acts quicker than the endocrine system. The rest period lasted 15 minutes. In another study, S. F. Lewis had participants perform various exercises, such as the arm curl, as compared to leg training. They found that, "norepinephrine and epinephrine increased exponentially in relation to work intensity. The most pronounced increases in both catecholamines occurred between 75 and 100% of muscle group-specific maximal oxygen uptake ( $P < 0.05$ ), particularly for two-leg cycling (46)."

This adds more confirmation to our 75-100 V<sub>02</sub> max trend.

Galbo also tested the effects of prolonged exercise for a mean (average) time of 20-80 minutes. Participants held their V<sub>02</sub> max at approximately 75 percent. Results were as follows:



At rest E levels were at 0.05, after 40 minutes they rose to 0.12, when 60 was reached the levels rose to .24, and after 80 E rose to 0.33 ng/ml, and again fell to .07 after 15 minutes of rest. Thus, epinephrine levels appear to also be time-dependent. That is, at 75 percent V02 max, E rises positively in respect to time.



NE followed a similar pattern. At rest they were .34, after 40 minutes they had risen to 1.20, during the 60-minute juncture 1.44 had been reached, and finally 1.51 after 80 minutes.

From these results, a trend appears which is consistent with the sympathoadrenal system. That is, NE is activated quicker, but at longer levels E becomes more and more significant. Galbo's results have also been confirmed in similar studies (21).

## Catecholamine Response to Resistance Training

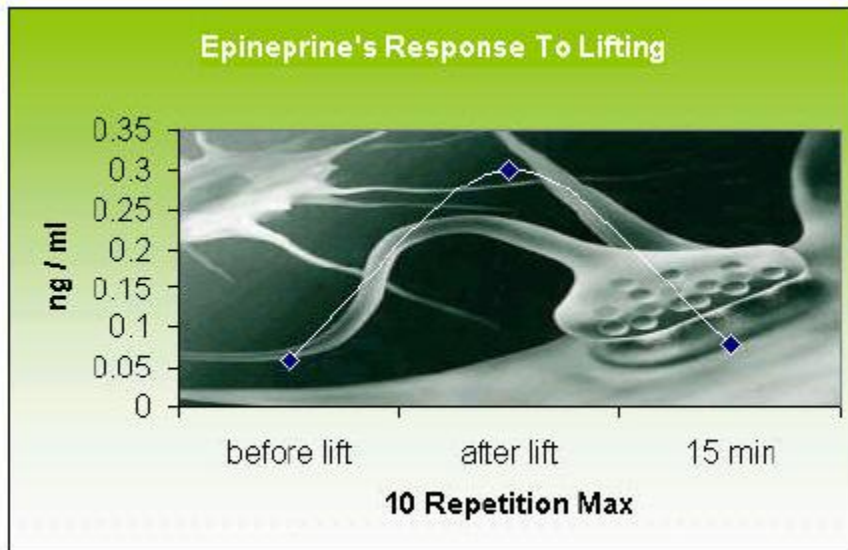
First, studies have been conducted at the 10-15 repetition range (BB rep range). If failure is reached, the response between the two protocols (10 vs. 15 repetitions) appears to be similar. Bush JA et al. tested just this scenario ( ).

Purpose: "The purpose of this study was to examine the effect of dynamic resistance exercise on the response patterns of adrenal medullary neurohormones in strength-trained men."

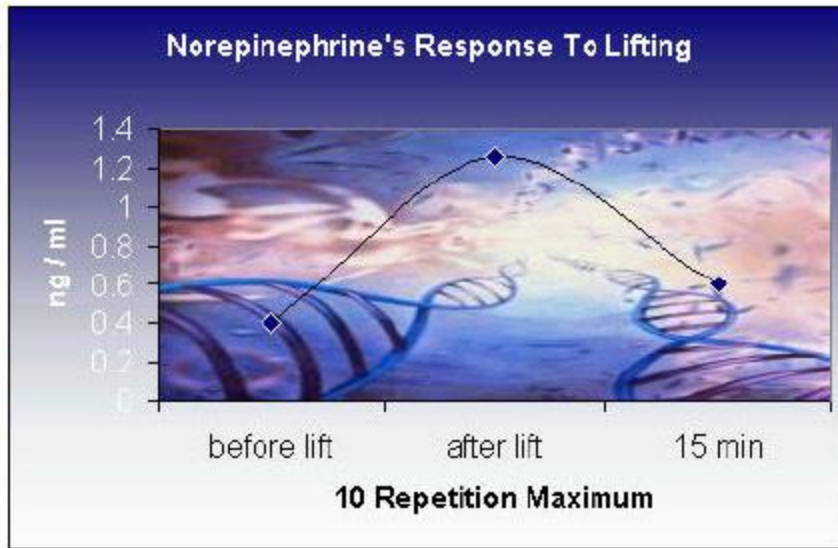
Protocol: A high force vs. high power protocol was given at the same work load. For example, 75 pounds lifted twice is the same work load as 150 lifted once. In this case, relative work loads were given in either a 10 rep sequence, or a 15 rep sequence.

Results: "Plasma epinephrine was significantly increased from baseline at R-0 and returned to baseline at R-15 for both protocols... These results indicate that the adrenal medulla was activated in response to the acute stress of both types of heavy resistance exercise."

Using their study and studies conducted by Kraemer et al., I have put together in graphical form the response of E and NE in regards to dynamic (weight lifting) resistance training, using a 10 repetition maximum set (4, 24).



We see that before the lift E was at .06, while after it had risen to .3, and dropped back to base levels after 15 minutes of rest.



Similar results were obtained for NE. That is, at rest, levels were at .4, but rose to 1.26 after the set was completed.

### Further Effects

We see that E and NE are related to intensity of VO<sub>2</sub> max, as well as maximal exertion and muscular force in dynamic resistance training. There are other factors involved, however, such as muscle mass. That is, catecholamines levels tend to be markedly higher with the largest activated muscle masses (46).

One question is what are the chronic effects of E and NE? That is, do they change with training? The answer here is tricky. For example, at the same workload, E and NE would lower in a conditioned vs. unconditioned individual. But again, this is obvious, as an unconditioned individual would be less able to handle strenuous exercise at a particular level than would a conditioned athlete (i.e. a 10 minute mile may be difficult for someone not trained to run, but would not even be a warm-up for a trained individual). Our concern is with relative levels of intensity. This is what I mean:

Individual X = Less conditioned

Individual Y = Greater conditioning

Both train at their 85 percent V<sub>O</sub>2 max intensities. Who secretes more catecholamines, or are they the same?

Greive and colleagues, in the journal of Applied Physiology, tested such a question!

Nine healthy individuals who were untrained participated in a 10-week study.

Individuals trained at 65-85 percent of their V<sub>O</sub>2 max for this time period, and increased their Max intake by 20 percent. They found that (23):

1. "Plasma NE concentrations increased progressively as exercise intensity increased from 60 to 85% of O<sub>2</sub> max both before and after training." This is in agreement with the studies above.

2. Here is the surprise! "Plasma NE concentrations were significantly higher in the trained compared with the untrained state at exercise intensities of 65-85% of O<sub>2</sub> max."

From this, they conclude that NE levels are related to both relative and "absolute" work loads. They also bring up the point that a person with double the V<sub>O<sub>2</sub></sub> max, working at 75 percent V<sub>O<sub>2</sub></sub>, will require twofold more substrate and oxygen use than their counterpart. "Clearly, stimulation of glycogenolysis, lipolysis, and cardiovascular function must be greater to make possible exercise requiring 45 ml · kg<sup>-1</sup> · min<sup>-1</sup> (i.e., 75% of an O<sub>2</sub> max of 60 ml · kg<sup>-1</sup> · min<sup>-1</sup>) than for exercise requiring 22.5 ml · kg<sup>-1</sup> · min<sup>-1</sup> (i.e., 75% of a O<sub>2</sub> max of 30 ml · kg<sup>-1</sup> · min<sup>-1</sup>)."

### Further Applications

Epinephrine and Norepinephrine are powerful fat burners. They are clearly related to absolute work load, which means that a person in better cardiovascular shape will have a greater capacity to burn fat than a person who can barely walk on the treadmill! It is for this reason that I stress the importance of cardiovascular conditioning.

We also see that even at 75 percent V<sub>O<sub>2</sub></sub> max, E and NE are very much time-dependent. Is there a way to get more out of longer cardio sessions? Indeed there is. Begin by performing a 10-15 minute all out session of incremental exercise. Start at 50 percent and increase the intensity every 30 seconds until you have reached your ultimate threshold. After this, lower the intensity to 75 percent and continue for the final 20-30 minutes of your session. You will burn a tremendously greater amount of fat than you otherwise would have!

Next month, we will see that epinephrine has a powerful application on pre- and mid-workout nutrition!

### Conclusion

As we have seen, the human body is a marvel beyond our wildest comprehensions. It is at times like this when we need to consider the verse (1):

Isaiah 55:6-13

6 Seek ye the LORD while he may be found, call ye upon him while he is near: 7 Let the wicked forsake his way, and the unrighteous man his thoughts: and let him return unto the LORD, and he will have mercy upon him; and to our God, for he will abundantly pardon. 8 For my thoughts are not your thoughts, neither are your ways my ways, saith the LORD. 9 For as the heavens are higher than the earth, so are my ways higher than your ways, and my thoughts than your thoughts.

We need to break this down. First God states (1):

**1.** "Seek ye the LORD while he may be found, call ye upon him while he is near"

There will be a time when this option is no longer available to those who reject his offer.

**2. "For my thoughts are not your thoughts, neither are your ways my ways"**

Though this is true, the conclusion to come to is obvious. We need to find out what his thoughts are, and what his ways are. This can be found in his infallible word, the Bible.

**3.** Though our ways are not his ways, we have no excuse of not seeking him. In fact, we are without excuse:

In Romans we find the following:

"Romans 1: 20 For the invisible things of him from the creation of the world are clearly seen, being understood by the things that are made, even his eternal power and Godhead; so F7 that they are without excuse: 21 Because that, when they knew God, they glorified him not as God, neither were thankful; but became vain in their imaginations, and their foolish heart was darkened. 22 Professing themselves to be wise, they became fools, 23 And changed the glory of the uncorruptible God into an image made like to corruptible man, and to birds, and fourfooted beasts, and creeping things. 24 Wherefore God also gave them up to uncleanness through the lusts of their own hearts, to dishonour their own bodies between themselves: 25 Who changed the truth of God into a lie, and worshipped and served the creature more than the Creator, who is blessed for ever. Amen. "

In other words, the things of God are so clearly seen that they are without excuse. And we know that: "27 it is appointed unto men once to die, but after this the judgment. " Thankfully, the verse also states the following fact: "28 So Christ was once offered to bear the sins of many; and unto them that look for him shall he appear the second time without sin unto salvation. "

It is also shown in the scriptures that "Eye hath not seen, nor ear heard, neither have entered into the heart of man, the things which God hath prepared for them that love him. "

If you have not accepted Christ as your savior today, simply ask him into your heart, and repent of your sins and you will be cleansed of them, and if you will, a new and exciting life awaits you the minute you make this decision!

Yours in Sport,

Jacob Wilson [jwilson@abcbodybuilding.com](mailto:jwilson@abcbodybuilding.com)

President Abcbodybuilding/Co-Editor of the Journal of HYPERplasia Research

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